Internet Interventions 25 (2021) 100407

Contents lists available at ScienceDirect

Internet Interventions

journal homepage: www.elsevier.com/locate/invent

# Using virtual reality to target positive autobiographical memory in individuals with moderate-to-moderately severe depressive symptoms: A single case experimental design

Javier Fernandez-Alvarez [a], Desirée Colombo [b,*], Carlos Suso-Ribera [b], Alice Chirico [c], Silvia Serino [a], Daniele Di Lernia [a], Azucena García Palacios [b,d], Giuseppe Riva [a,e], Cristina Botella [b,d]

[a] Humane Technology Lab., Università Cattolica del Sacro Cuore, Milan, Italy
[b] Department of Basic Psychology, Clinic and Psychobiology, Universidad Jaume I, Castellon, Spain
[c] Università Cattolica del Sacro Cuore, Milan, Italy
[d] CIBER Fisiopatología Obesidad y Nutrición (CIBERobn), Instituto Salud Carlos III, Madrid, Spain
[e] Applied Technology for Neuro-Psychology Lab, IRCCS Istituto Auxologico Italiano, Milan, Italy

ARTICLE INFO

*Keywords:*
Autobiographical memory
Overgeneral memory
Virtual reality
Reminiscence
Single case study

ABSTRACT

So far, several aspects of autobiographical memory (AM) have been found to be impaired in depression. Among others, depressed patients show the tendency to recall more negative than positive events (i.e., negative bias) and usually retrieve memories that lack of specificity and details (i.e., overgeneral memories). Based on this, we designed an AM task enhanced by the use of virtual reality (VR) to specifically train the recall of positive memories. Using a single-case, multiple baseline experimental design, we explored the effects of a brief intervention consisting of two sessions of this training in a sample of 18 individuals with moderate-to-moderately severe depressive symptoms. According to the results, changes occurred at the short term only. In particular, almost all participants reported a significant improvement in at least one outcome measure 0–3 days after the intervention. However, these clinical gains were not maintained in the mid-term (from day 4 to 10). The present findings do not support the efficacy of our VR-based AM recall treatment as a standalone intervention. Nevertheless, it might represent a suitable procedure to obtain immediate and/or short-term improvements. It might also serve as a valid component to be integrated in broader protocols for patients with moderate-to-moderately severe depressive symptoms.

## 1. Introduction

Major Depressive Disorder (MDD) constitutes one of the most disabling mental health conditions worldwide, entailing mood disturbances, loss of interest in daily activities, disturbed sleep and appetite, loss of energy, and psychomotor retardation or agitation. With a lifetime prevalence of 15% (Wittchen et al., 2011), MDD is associated with a wide range of negative consequences, such as reduced quality of life and poor social functioning (Angermeyer et al., 2002; De Vos et al., 2017; Hirschfeld et al., 2000). Interestingly, ample evidence supports the role of cognitive factors in the onset and maintenance of depression (Beck and Haigh, 2014; Gotlib and Joormann, 2010). Among these factors, a growing body of research suggested the significant association between depression and autobiographical memory (AM) impairments.

AM can be defined as the set of personal experiences that people remember about their own life (Conway, 1987). These memories are argued to be a core structure of an individual's identity (Brewer, 1994), as well as a key source of information when providing the Self with a sense of unity and coherence (Romano et al., 2020). Retrieving autobiographical events is also known to facilitate certain processes closely associated with the Self, such as problem solving, future planning, and openness towards the future (Pascuzzi and Smorti, 2017). Most importantly, AM recall entails re-experiencing past mental states, including believes, emotions, thoughts, and desires (Klein, 2015). If positive, the recall of such events (e.g., positive reminiscence) is considered an effective positive emotion regulation strategy (Bryant et al., 2005;

* Corresponding author at: Universitat Jaume I, Av. Sos Baynat, s/n, 12071, Castellón, Spain.
*E-mail address:* dcolombo@uji.es (D. Colombo).

https://doi.org/10.1016/j.invent.2021.100407
Received 3 December 2020; Received in revised form 16 April 2021; Accepted 21 May 2021
Available online 27 May 2021

Quoidbach et al., 2010), that is, a strategy that allows to enhance positive emotions in the present.

To date, several aspects of AM have been shown to be impaired in individuals showing depressive symptoms. As a consequence of a negative bias (Gotlib and Joormann, 2010; Neshat-Doost et al., 1998), depressed patients tend to retrieve negative memories to a greater extent than positive ones (Gaddy and Ingram, 2014; Matt et al., 1992) and to underestimate the positivity of past positive experiences (Colombo et al., 2019, 2020b). Furthermore, depression has been associated with overgeneral memories, i.e. the tendency to retrieve routine actions rather than specific events, as well as memories that lack in specificity and details (Dalgleish and Werner-Seidler, 2014; Sumner et al., 2010; Williams et al., 2007). Finally, depressed individuals have been found to retrieve memories from a third-person perspective, as if the events were unrelated to them (Lemogne et al., 2006; Siedlecki, 2015). Especially in the case of positive memories, the use of the third-person perspective might be considered maladaptive, as it increases the emotional distancing from past positive episodes and thus prevents people from using them to enhance positive affect (PA) in the present (Wallace-Hadrill and Kamboj, 2016).

AM impairments might be important to understand some of the key features underlying depressive symptoms. For example, poor AM retrieval seems to be intimately related to ruminative style thinking (Dalgleish and Werner-Seidler, 2014; Watkins and Teasdale, 2001), which constitutes a hallmark of depression (Aldao et al., 2014). In this sense, a reduction in rumination has been associated with a decrease in overgeneral memories (Watkins and Teasdale, 2001). Additionally, a maladaptive use of AM is likely to affect the use of positive reminiscence as a mood-repair mechanism (Burt et al., 1995; Matt et al., 1992), which in turn might explain the difficulties of depressed patients in using pleasant memories to augment PA. Interestingly, recent studies have demonstrated the feasibility and efficacy of AM interventions (Ahmadi Forooshani et al., 2020; Dalgleish and Werner-Seidler, 2014), which further confirms the potential role of memory in the maintenance of depressed mood. Consequently, addressing AM impairments might represent a useful therapeutic tool to be used in individuals with depressive symptoms, potentially fostering positive emotion regulation and, more generally, enhancing PA levels. Because AM recall has been found to be more effective than other mood induction techniques for the elicitation of positive emotions (Jallais and Gilet, 2010; Strack et al., 1985; Zhang et al., 2014), the development of innovative therapeutic strategies that target the ability to recall positive memories seems promising.

Thanks to its long-standing tradition in the clinical field and to the growing body of evidence supporting its efficacy (Botella et al., 2017; Carl et al., 2019; Lindner et al., 2019) in the treatment of depression (Falconer et al., 2016; Migoya-Borja et al., 2020; Shah et al., 2015; for a review see: Zeng et al., 2018), Virtual Reality (VR) might be a key therapeutic tool also in the field of AM interventions. First, VR can facilitate a spatial reference for the recall of past events through the exposure to realistic and personally significant scenarios (Baños et al., 2004; Baños et al., 2008; Botella et al., 2004), thus functioning as a sort of projector of the memory. Second, there is evidence showing that the adoption of VR to elicit emotions is highly effective (Jallais and Gilet, 2010; Strack et al., 1985; Zhang et al., 2014). This suggests that combining AM recall with VR could further enhance the intensity of the emotions elicited, which in turn might improve the quality of the recalled memories in terms of vividness and/or specificity. Finally, the immersiveness of VR leads to re-experiencing an event with one's own eyes, thus forcing the recall of an experience from a first-person perspective. In particular, the off-the-shelf freely available application *Google Earth VR* opens up to unprecedent opportunities in the field of AM. *Google Earth VR* permits travelling to different places around the world and experiencing a "sense of being there" from a first-person perspective, allowing the individual to virtually access the place where an event took place. Together, the use of this VR-based application may therefore enhance the retrieve of positive episodes, which might in turn increase the specificity and vividness of such memories.

In the present work, we recruited a sample of 18 individuals with moderate-to-moderately severe depressive symptoms. The main objective of the study was to examine the effects of a brief intervention consisting of 2 sessions of a VR-based AM recall task. Consistent with the previous literature, we expected that the AM intervention would lead to increased PA (Jallais and Gilet, 2010; Strack et al., 1985; Zhang et al., 2014) and reduced depressive symptoms (Dalgleish and Werner-Seidler, 2014). Furthermore, we hypothesized that the intervention would also improve patients' emotion regulation skills. First, we hypothesized that the VR-based AM intervention would enhance patients' positive reminiscence and, more specifically, the frequency of use of this strategy and the vividness of the recalled past positive memories. Second, because positive reminiscence is considered to be a positive emotion regulation strategy to upregulate momentary positive emotions (Bryant et al., 2005; Quoidbach et al., 2015), we also hypothesized that the brief intervention would enhance daily savoring levels (i.e., enjoyment of positive experiences). Finally, and consistent with previous studies, we expected to observe decreased rumination levels after the intervention (Watkins and Teasdale, 2001).

## 2. Material and methods

### 2.1. Inclusion and exclusion criteria

To be eligible for the study, individuals had to meet the following criteria: Being aged between 18 and 65 years, being able to read and understand Spanish, and scoring between 10 and 19 at the Patient Health Questionnaire-9 (PHQ-9) (i.e., moderate-to-moderately severe depressive symptoms) (Kroenke et al., 2001). Individuals with a score higher than 19 (i.e., severe depressive symptoms) were offered a psychological treatment at the Psychological Care Centre of the University.

We excluded individuals currently suffering from a severe mental disorder as assessed with the Mini International Neuropsychiatric Interview Version 5.0.0 (MINI) (Ferrando et al., 2000), such as alcohol and/or substance dependence disorder, bipolar disorder, psychotic disorder or dementia. Moreover, we excluded participants who were already receiving a psychological treatment, as it would have made it difficult to disentangle the clinical gains associated with the VR-based protocol from the improvements linked to the psychological treatment.

Inclusion and exclusion criteria were assessed one week before the beginning of the study. The protocol was approved by the ethics committee of the Jaume I University (number: 17/2018) and informed consent was obtained from all participants.

### 2.2. Sample

The study was conducted at the Jaume I University's Psychological Care Center (Spain). The sample was composed of 16 females and 2 males ($n = 18$), with a mean age of 21.61 years ($SD = 3.24$). More details are reported in Table 1.

### 2.3. Study design

Traditionally, the examination of the efficacy of interventions has been dominated by randomized controlled trials with large samples, in which the effect of the proposed treatment is tested using average group scores. While this methodology has clearly provided valuable information for the advance of treatments, it also has important limitations, including the need for control or waiting list conditions to control for the placebo effect, the need to recruit large samples, and the inflexibility in the procedures implemented once the trial has started (Kratochwill et al., 2010). As a response to the previous, single case experimental designs (SCEDs) are gaining ground in clinical research due to their

**Table 1**
Sociodemographic and clinical characteristics of the recruited sample. Group 1 included 8 days of baseline (phase A) and 10 days of treatment monitoring (phase B); Group 2 corresponds to 9 days of baseline (phase A) and 9 days of treatment monitoring (phase B); Group 3 had 10 days of baseline (phase A) and 8 days of treatment monitoring (phase B). (PHQ-9 = Patient Health Questionnaire – 9 items).

| ID | Age | Sex | Group | PHQ-9 |
|---|---|---|---|---|
| 1 | 23 | f | 3 | 11 |
| 2 | 19 | f | 2 | 10 |
| 3 | 20 | m | 3 | 14 |
| 4 | 25 | f | 2 | 13 |
| 5 | 26 | f | 1 | 11 |
| 6 | 20 | m | 1 | 15 |
| 7 | 20 | f | 1 | 15 |
| 8 | 18 | f | 1 | 13 |
| 9 | 21 | f | 2 | 16 |
| 10 | 20 | f | 3 | 10 |
| 11 | 21 | f | 3 | 10 |
| 12 | 20 | f | 2 | 10 |
| 13 | 19 | f | 3 | 15 |
| 14 | 19 | f | 2 | 10 |
| 15 | 23 | f | 1 | 10 |
| 16 | 31 | f | 3 | 10 |
| 17 | 24 | f | 1 | 11 |
| 18 | 20 | f | 2 | 12 |

flexibility, their utility when collecting large samples is difficult or when exploring the preliminary feasibility and effectiveness of a new treatment, and thanks to the fact that no control condition is required (each participant's baseline is used as control). In the past, SCEDs have been challenging due to their need for continuous assessment. However, thanks to the Internet and the explosion of smartphones, ecological momentary assessment is now more feasible than ever (Suso-Ribera et al., 2018).

The present study is a single-case, multiple baseline experimental design (Kazdin, 2011), a type of SCED that assigns individuals to different starts of the treatment phase. For every baseline, an AB design (A = baseline, B = treatment) was conducted. More specifically, the design included three different baseline lengths, as recommended by guidelines (Kratochwill et al., 2013). Participants were randomly assigned to one of the three groups: Group 1, which included 8 days of baseline (phase A) and 10 days of treatment monitoring (phase B); group 2, which included 9 days of baseline (phase A) and 9 days of treatment monitoring (phase B); and group 3, which included 10 days of baseline (phase A) and 8 days of treatment monitoring (phase B). Regarding treatment (B phase), all participants received two intervention sessions on two consecutive days. Thus, group 1 received the treatment on days 9 and 10, group 2 received the treatment on days 10 and 11, and group 3 received the treatment on days 11 and 12. Considering the potential presence of missing data, the duration of the baseline and follow-up periods was chosen in order to ensure that 5 assessments per participant could be obtained, which is the minimum recommended to perform analyses in SCEDs (Kratochwill et al., 2010).

Daily assessments were collected by means of Qualtrics, a web-based platform that allows to send customized online surveys at specific time points during the day. Participants were prompted once a day (08:30 pm) in order to complete a set of daily psychological measures about depressive symptoms, positive and negative affect (NA), emotion regulation skills. See Section 2.7 for a detailed description of the daily measures. Participants were given two hours and a half to access the survey (until 11.00 pm). After that period of time, the assessment was marked as missing. The mean delay between prompt time and assessment completion in our sample was 24 min (*SD* = 31.63).

The study was conducted in accordance with the Single-Case Reporting Guidelines in Behavioral Interventions (SCRIBE) checklist for SCEDs (Tate et al., 2016).

### 2.4. Intervention

All participants received two VR-based sessions on two consecutive days, each of which lasted between 30 and 45 min. The application *Google Earth VR* was used in both sessions. *Google Earth VR* allows users to place themselves anywhere in the world and to experience the feeling of "being there" through their own eyes. Participants entered the virtual scenario by means of a head-mounted display (Oculus Rift DK2) connected to a laptop (Alienware 17 R5 with NVIDIA GTX1070 graphics card and Intel i7 CPU) on which the application was run. The setup also included two sensors and two hand-controllers, which enabled participants to explore the virtual environment.

In each session, participants were asked to recall a positive memory of their life with the following instructions:

> "*We would like you to recall a positive memory, something specific that occurred in your life and during which you experienced intense positive emotions most of the time. You should try to identify a memory that took place in a specific, public place anywhere in the world, for example, in a square, at a beach, at a street, etc. We kindly ask you to try to recall the exact name/address of that place, as we will take you there using virtual reality. You will be free to observe or move through the environment, while trying to recall aloud everything you can remember about that memory; for example, how you were you feeling, with whom you were sharing the event, etc.*"

Before starting the task, participants were also provided with some examples that clarified the meaning of "specific event". Subsequently, they were given all the time they needed to think about a positive memory and to write down its spatial details. Participants were able to complete this task in less than 5 min.

Participants were subsequently asked to wear the VR head-mounted display while maintaining their eyes closed, until the researcher could find the exact place where the recalled event took place. Once ready, participants were asked to open their eyes and start describing their memory. No time limit was set during the recall phase; that is, participants were free to talk and describe their memory for as long as they wanted to. Each memory recall typically lasted between 5 and 15 min.

The same procedure was repeated twice, thus resulting in the recall of two positive memories for each session.

### 2.5. Experimental check

In order to explore the short-term efficacy of the VR-based AM task to induce positive emotions (i.e., experimental check), participants were instructed to complete the PANAS and to rate the intensity of seven low- and high-arousal positive emotions (happiness, diversion, gratitude, hope, pride, serenity, and excitement) on a 0–100 scale ("To what extent are you currently experiencing the following emotions?" 0 = not at all, 100 = extremely) at the beginning of the session and after each of the two memory recall procedures. In both cases, the instructions referred to the *momentary* experience of emotions. Because the procedure had not been tested before, the experimental check analyses allowed to control for the efficacy of the procedure in inducing positive emotional states.

### 2.6. Study outcomes

#### 2.6.1. Affect

Based on previous studies (Colombo et al., 2020a; Colombo et al., 2020b), we used two 0–100 single items (0 = not at all; 100 = extremely) evaluating daily PA ("To what extent have you experienced positive emotions today?") and NA levels ("To what extent have you experienced negative emotions today?").

#### 2.6.2. Depressive symptoms

Daily depressive symptoms were assessed using the Patient Health

Questionnaire–2 (PHQ-2) (Kroenke et al., 2003), the short version of the PHQ-9 (Diez-Quevedo et al., 2001; Kroenke et al., 2001), a self-report questionnaire for the assessment of depressive symptoms. The PHQ-2 has been shown to have good psychometric properties (Kroenke et al., 2003) and to be an adequate tool to capture daily depressive symptoms through mobile assessments (Bauer et al., 2018). The original instructions were modified in order to make them more suitable for daily administration ("*Today, how often have you been bothered by any of the following problems?*").

#### 2.6.3. Emotion regulation

In order to create ad hoc single items assessing daily emotion regulation, we conducted a focus group with five experts in the field. Disagreements were resolved through consensus and, when needed, the opinion from another researcher with expertise in emotion regulation was obtained. The following items rated on a 0–100 scale (0 = not at all; 100 = extremely) were finally created: Daily rumination ("Today, I have been rehashing in my mind the things I've said or done"), daily positive reminiscence (frequency: "Today, I have recalled positive memories of my life"; vividness: "Today, it has been easy to retrieve positive memories in a vivid and clear way"), and daily savoring levels ("Today, I have been able to concentrate and savour/took the most of the things I have done").

### 2.7. Procedure

Participants were recruited through poster advertisements at the Jaume I University and several social media platforms. Individuals willing to participate in the study contacted our laboratory by email. One week before the beginning of the study, the potential participants were sent a link to complete the PHQ-9 online. Those meeting the inclusion criteria on the PHQ-9 scores were invited to attend the laboratory during the following days in order to receive more detailed information about the study, as well as to further investigate their eligibility through the administration of the MINI. If the criteria for study participation were satisfied, individuals were asked to sign the informed consent.

During the whole duration of the study, participants could contact the researchers in order to discuss any difficulties or doubts about the protocol. When detecting missing data in the daily evaluations (at least two consecutive missing data entries), participants were contacted by email and were encouraged to adhere to the assessment protocol.

At the end of the study, participants returned to the laboratory for a final debriefing session. A remuneration of 20 euros was given to participants who completed the whole protocol.

### 2.8. Data analysis

First, repeated measure ANOVAs were conducted. By doing this, we explored whether there was a significant change in positive and negative emotions after the VR-based AM recall procedure at the group level (i.e., experimental check). Since many comparisons were performed, the Holm-Bonferroni Method was applied to correct for familywise error rates for multiple hypothesis tests, obtaining a p-value of 0.002.

To test the main study hypotheses for every individual, baseline-to-posttreatment changes in daily measures were calculated by means of a non-overlap of all pairs (NAP) analysis. In the NAP, every single point in the baseline phase (A) is compared against every point in the treatment phase (B). This measure of overlap is recommended over other overlap measures that use partial data only, such as the percent of non-overlapping data and percent of data points exceeding the median (Parker et al., 2014). The NAP provides a percentage of non-overlap (i.e., improvement) when comparing the baseline and the treatment phase. This non-overlap index ranges from 0 to 100 and higher scores indicate less overlap (greater treatment effectiveness).

In terms of NAP interpretation, the median non-overlap of past treatment studies has been proposed as a good comparison measure for interpretation (Gómez-Pérez et al., 2020; Parker et al., 2011). NAP scores greater than 96% should be interpreted as very large intervention effects (i.e., corresponding to the median effects of investigations above the 75th percentile of previously published effects in different studies). NAP indices between 66% and 96% would represent moderate-to-large effects (median NAP effects of investigations between percentile 50 and 75). Mild-to-moderate treatment effects would correspond to NAPs between 38% and 66% (median effects of studies between the 25th and 50th percentile of published effects). Finally, a NAP below 38% corresponds to poor treatment effect (i.e., the 25th percentile of smallest NAP scores reported across studies).

## 3. Results

### 3.1. Experimental check

Table 2 shows the results of the repeated measures ANOVAs that explored the effects of the VR-based AM task on momentary affect. In both sessions, participants showed significant higher levels of PA and positive emotions as well as decreased NA rates following the AM procedure. Interestingly, while in the first session no significant difference was observed between the two VR tasks, in the second session participants also showed increased levels of PA between the first and the second recalls.

Overall, our results suggest that the VR-based AM procedure successfully elicited positive emotions and reduced negative ones at the group level.

### 3.2. Effects of the AM VR-based task: changes at the individual level

According to the NAP analyses, the majority of participants did not show a significant improvement on most variables of interest (Table 3).

However, it is of particular relevance to highlight that those participants who did present improvements in one outcome were likely to improve in several outcomes (i.e., generalization of effects).

After a visual inspection of the graphical representations used to conduct the NAP analyses presented in Table 3, a secondary analysis was conducted. Specifically, we noticed that many variables were likely to improve immediately after the intervention (e.g., a couple of days later), although these improvements were not maintained over time (see two examples in Fig. 1).

In order to explore the extent to which the treatment was effective in the short-term, we repeated the NAP analyses. More specifically, the post-intervention phase was divided into three time-intervals: 0–3 days, 4–6 days and 7–10 days. Each time interval was therefore compared to the baseline (Table 4).

Compared to 4–6 days and 7–10 days phases, the results revealed that almost all participants presented a significant improvement in at least one of the outcomes immediately after the intervention (i.e., 0–3 days), with the only exception of subject 7. Specifically, the percentage of participants that reported a moderate-to-large improvement was: 72% for PA; 61% for positive reminiscence – vividness; 67% for positive reminiscence – frequency; 67% for savoring; 50% for NA, 39% for rumination and 44% for depressive symptoms. In relation to participant number 7, who did not show any significant improvement, it is interesting to note that this participant had the second lowest average baseline NA score ($M = 16.86$) and the fifth highest average baseline PA score ($M = 70.71$) from the sample. Specifically, the average baseline PA and NA scores in the sample were 62.6 ($SD = 11.2$, range = [41.3, 80.8]) and 34.7 ($SD = 15.6$, range = [0.6, 60.6]), respectively. Similar to participant 7, participants 1 and 3, who also presented a poor response to the intervention, also had a pattern characterized by high baseline PA ($M_1 = 72.0$; $M_3 = 65.2$) and low baseline NA ($M_1 = 0.06$; $M_3 = 21.0$) when compared with the remaining participants. This means that the participants with a poor response were generally approximately 1 *SD*

**Table 2**
Results of the repeated measures ANOVA analyses to compare PA, NA and positive emotions among the three time points (T0 = baseline; T1 = first recall, T2 = second recall). PA and NA measures were assessed through the PANAS, whereas positive emotions were measured through 0–100 items. PA: positive affect; NA: negative affect. In the ANOVAs, the baseline score was the reference in the comparison with first and second recalls. The Holm-Bonferroni Method was used to correct for familywise error rates for multiple hypothesis tests.

| | | Session 1 | | | | Session 2 | | | |
|---|---|---|---|---|---|---|---|---|---|
| Outcome variable | Condition | *M* | *SD* | *T0* | *T1* | *M* | *SD* | *T0* | *T1* |
| PANAS-PA | *T0* | 26.83 | 4.99 | | | 23.83 | 8.06 | | |
| | *T1* | 34.39 | 7.82 | * | | 31.89 | 8.71 | * | |
| | T2 | 36.06 | 8.35 | * | | 35.28 | 9.47 | * | * |
| | *T0* | 15.61 | 3.52 | | | 14.67 | 4.68 | | |
| PANAS-NA | *T1* | 11.56 | 2.12 | * | | 11.78 | 2.34 | | |
| | T2 | 10.89 | 1.49 | * | | 11.39 | 1.69 | | |
| | *T0* | 55.17 | 18.2 | | | 47.22 | 20.6 | | |
| HAPPINESS | *T1* | 84.11 | 15.9 | * | | 76.89 | 19.9 | * | |
| | T2 | 89.78 | 10.9 | * | | 85.06 | 12.5 | * | |
| | *T0* | 40.56 | 19.9 | | | 36.89 | 21.6 | | |
| DIVERSION | *T1* | 76.72 | 18.9 | * | | 67.39 | 26.2 | * | |
| | T2 | 82.39 | 16.1 | * | | 77.72 | 19.3 | * | |
| | *T0* | 47.33 | 20.5 | | | 39.5 | 22.2 | | |
| GRATITUD | *T1* | 80.28 | 16.2 | * | | 75 | 21.1 | * | |
| | T2 | 82.61 | 14.9 | * | | 84.28 | 15.6 | * | |
| | *T0* | 55.67 | 23.3 | | | 46.39 | 22.9 | | |
| HOPE | *T1* | 73.39 | 22.2 | | | 71.61 | 23.9 | * | |
| | T2 | 74.83 | 19.7 | | | 78.11 | 18.1 | * | |
| | *T0* | 38.67 | 24.4 | | | 36.94 | 22.4 | | |
| PRIDE | *T1* | 68.22 | 29.9 | * | | 65.5 | 27.3 | * | |
| | T2 | 74.72 | 25.4 | * | | 74.89 | 24.9 | * | |
| | *T0* | 47.61 | 20.4 | | | 50.94 | 26.3 | | |
| SERENITY | *T1* | 72.89 | 24.6 | | | 70.67 | 25.6 | | |
| | T2 | 75.33 | 23.9 | | | 75.39 | 27.4 | * | |
| | *T0* | 55.17 | 18.7 | | | 43.61 | 22.5 | | |
| ENTHUSIASM | *T1* | 81.33 | 18.1 | * | | 68.33 | 27.3 | * | |
| | T2 | 82 | 17.7 | * | | 82.67 | 17.7 | * | |

* $p < .002$.

**Table 3**
Results of the NAP analyses. PA: positive affect; NA: negative affect; PHQ2: Patient Health Questionnaire – 2.

| ID | Group | Phase A assessments | Phase B assessments | PA | NA | PHQ2 | Rumination | Reminiscence frequency | Reminiscence vividness | Savoring |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 5/10 | 7/8 | **68.6**[a] | 0 | 50 | 11.4 | **80**[a] | 58.9 | 37.1 |
| 2 | 2 | 8/9 | 9/9 | 61.8 | **72.9**[a] | **70.8**[a] | **70.8**[a] | 60.4 | **74.3**[a] | **69.4**[a] |
| 3 | 3 | 10/10 | 8/8 | 30 | 21.5 | 15 | 6.9 | 43.8 | 59.4 | 46.9 |
| 4 | 2 | 9/9 | 8/9 | 52.8 | 57.6 | 43.8 | **66**[a] | 31.9 | 56.8 | 28.5 |
| 5 | 1 | 8/8 | 10/10 | 35 | 43.1 | 53.8 | **85**[a] | 22.5 | 41.2 | 51.2 |
| 6 | 1 | 8/8 | 10/10 | 63.1 | 63.7 | 60 | 25 | 52.5 | 41.2 | 55.6 |
| 7 | 1 | 7/8 | 10/10 | 39.3 | 46.4 | 57.1 | **67.1**[a] | 55.7 | 42.9 | **67.1**[a] |
| 8 | 1 | 7/8 | 9/10 | **78.6**[a] | 29.4 | 56.3 | 43.7 | **76.2**[a] | **77**[a] | **69.3**[a] |
| 9 | 2 | 8/9 | 9/9 | 43.1 | 54.9 | 52.8 | 40.3 | 63.9 | 41.2 | 50.7 |
| 10 | 3 | 9/10 | 7/8 | 49.1 | 58.7 | 61.1 | 55.6 | 57.1 | 55 | 47.6 |
| 11 | 3 | 9/9 | 9/9 | 61.8 | 46.3 | **77.2**[a] | **87**[a] | 59.9 | 57.4 | **80.9**[a] |
| 12 | 2 | 9/9 | 9/9 | **87.7**[a] | 54.3 | 63 | 29.6 | **74.1**[a] | **68.5**[a] | **90.1**[a] |
| 13 | 3 | 8/10 | 8/8 | 59.4 | 53.1 | **66**[a] | 52.6 | 54.7 | **66.1**[a] | 49.2 |
| 14 | 2 | 8/9 | 9/9 | 61.8 | 30.5 | 45.1 | 62.5 | 56.9 | 41.2 | 39.6 |
| 15 | 1 | 8/8 | 10/10 | **90**[a] | 55.0 | **71.2**[a] | **66.9** | 48.1 | 55 | **81.3**[a] |
| 16 | 3 | 10/10 | 8/8 | 51.3 | 58.8 | 60 | 28.1 | 50 | 58.9 | 65 |
| 17 | 1 | 8/8 | 10/10 | 45.6 | 60.6 | 47.5 | **68.1**[a] | 34.4 | 15.6 | 46.3 |
| 18 | 2 | 6/9 | 9/9 | 50 | 63 | **68.5**[a] | 65.7 | 29.6 | 22.2 | 55.3 |
| Moderate-to-large effect | | | | 4/18 | 1/18 | 5/18 | 7/18 | 3/18 | 4/18 | 6/18 |

Bold data indicates that the result is statistically significant.
[a] NAP indices over 66% (moderate-to-large effect).

above the sample score of average baseline PA (i.e., participant 1 and 7) and NA (i.e., participant 1, 3, and 7). An exception to this, however, was participant 18, who only improved in one outcome measure and presented average baseline PA and NA scores comparable with the sample mean ($M = 62.8$ and $M = 34.5$, respectively).

Compared to short-term changes, the number of outcomes in which the participants showed moderate-to-large improvements in the longer term (i.e., between 4 and 6 days and between 7 and 10 days) was much more modest. In addition, several participants did not reveal changes in any outcome at 4-to-6 ($n = 6$) and 7-to-10 days ($n = 9$) after the treatment.

## 4. Discussion

In the current study, we examined the effects of a brief intervention combining VR with a positive AM recall task. The aim was to test the efficacy of this intervention on affect, depressive symptoms, and emotion regulation skills in a sample of individuals with moderately and moderately severe depressive symptoms.

In order to confirm the efficacy of the VR-based AM task, we first

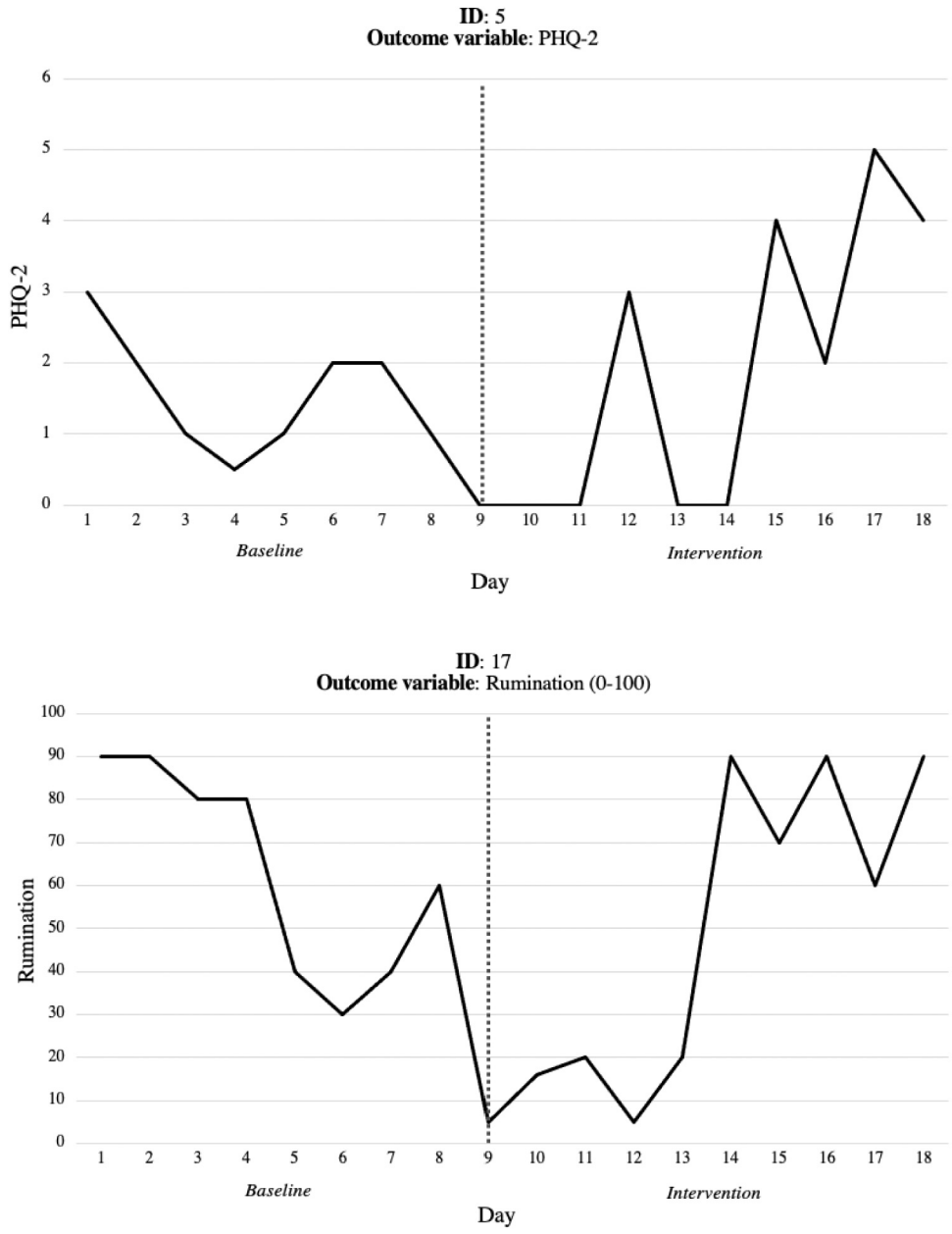


**Fig. 1.** Graphical representation of the evolution in daily depressive symptoms and rumination in two participants. The dotted line represents the beginning of the intervention. In both cases, significant short-term improvements were observed, which were not maintained over time.

explored whether the procedure could induce a significant change in participants' affective state. Compared to the baseline, participants showed increased levels of PA and positive emotions, and reduced levels of NA, thus confirming the efficacy of the VR-based AM task to elicit positive affective states in the short term. Interestingly, the experimental check also revealed that, in the first session, a single AM recall would have been sufficient to improve momentary PA. This was not the case for the second session. It might be that, after the novelty of the VR-based experience in the first session, participants lost their naiveness to the task, which consequently resulted in a reduced efficacy at inducing positive emotions, thus requiring a more intensive intervention (i.e., two AM recalls). While these findings are interesting, further studies are needed in order to clarify this point and explore whether one or two recall tasks are needed for each session of this VR-based AM intervention.

Although some AM training has already been developed (Ahmadi Forooshani et al., 2020), the novelty of our intervention relied on the use of VR to further enhance the retrieval of past positive memories. We hypothesized that the VR-based AM intervention would enhance patients' daily reminiscence, PA and savoring, as well as decrease daily rumination. The primary NAP analyses did not lead to the expected results and did not confirm our hypotheses. Indeed, just a few participants showed a significant improvement on the variables of interest. Therefore, our results do not support the efficacy of the proposed AM intervention as a standalone treatment for patients with moderate or moderately severe depressive symptoms. Although promising results have been pointed out by the previous literature, our findings are in line with a recent meta-analysis concluding that the available studies do not support the use of autobiographical memory-based interventions as standalone therapies to improve mental health problems (Ahmadi Forooshani et al., 2020).

Different to the previous lines, our hypotheses were partially confirmed by the secondary analyses. Indeed, the results observed in the short term (i.e., 0–3 days after the intervention) revealed significant

**Table 4**
Results of the NAP analyses comparing the baseline (phase A) to three time-intervals of the post-intervention phase: 0–3 days (phase $B^{I}$), 4–6 days (phase $B^{II}$) and 7–10 days (phase $B^{III}$). PA: positive affect; NA: negative affect; PHQ2: Patient Health Questionnaire – 2.

| | | A-$B^{I}$ | | | | | | | A-$B^{II}$ | | | | | | | A-$B^{III}$ | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Group | PA | NA | PHQ2 | Rumination | Reminiscence frequency | Reminiscence vividness | Savoring | PA | NA | PHQ2 | Rumination | Reminiscence frequency | Reminiscence vividness | Savoring | PA | NA | PHQ2 | Rumination | Reminiscence frequency | Reminiscence vividness | Savoring |
| 1 | 3 | 40.0 | 0.0 | 35.0 | 10.0 | **90.0**[a] | **75.0**[a] | 40.0 | **66.7**[a] | 0.0 | 46.7 | 20.0 | **66.7**[a] | 43.3 | 33.3 | 60.0 | 0.0 | **70.0** | 10.0 | **90.0**[a] | 60.0 | 40.0 |
| 2 | 2 | **83.3**[a] | **79.2**[a] | **75**[a] | 56.3 | 60.42 | **70.8**[a] | **95.8**[a] | 52.1 | **77.1**[a] | **75**[a] | 56.3 | 37.5 | 37.5 | 62.5 | 50.0 | 58.3 | 62.5 | 45.8 | 50.0 | 56.3 | 37.5 |
| 3 | 3 | 50.0 | 26.7 | 30.0 | 10.0 | **70.0**[a] | **75.0**[a] | 60.0 | 16.7 | 23.3 | 3.3 | 5.0 | 6.7 | 30.0 | 38.3 | 20.0 | 10.0 | 10.0 | 30 | 10.0 | 52.5 | 40.0 |
| 4 | 2 | **87**[a] | **90.7**[a] | **66.7**[a] | **66.7**[a] | **72.22**[a] | **81.5**[a] | 61.1 | 42.6 | 37.0 | 46.3 | 63 | 13.0 | 50.0 | 14.8 | 5.6 | 11.1 | 5.6 | **69.4**[a] | 0.0 | 5.6 | 11.1 |
| 5 | 1 | **68.8**[a] | **91.7**[a] | **100**[a] | **75**[a] | 25.0 | **79.2**[a] | **87.5**[a] | 43.8 | 37.5 | **68.8**[a] | **91.7**[a] | 50.0 | 45.8 | 45.8 | 3.1 | 10.9 | 7.8 | **84.4**[a] | 0.0 | 9.4 | 18.8 |
| 6 | 1 | **89.6**[a] | **91.7**[a] | **83.3**[a] | 56.3 | **72.92**[a] | 65 | **89.6**[a] | 33.3 | 58.3 | 50.0 | 4.2 | 43.8 | 31.3 | 33.3 | 53.1 | 46.9 | 50.0 | 12.5 | 43.8 | 31.3 | 46.9 |
| 7 | 1 | 28.6 | 2.4 | 35.7 | 47.6 | 19.05 | 26.2 | 23.8 | 33.3 | 61.9 | 47.6 | 52.4 | 26.2 | 31 | 47.6 | 50 | **67.9**[a] | **69.6**[a] | **67.9**[a] | **69.6**[a] | 64.3 | **71.4**[a] |
| 8 | 1 | **95.2**[a] | 33.3 | 42.9 | 42.9 | **80.95**[a] | **85.7**[a] | 42.9 | **78.6**[a] | 28.6 | 53.6 | 64.3 | **85.7**[a] | **100**[a] | **78.6**[a] | **66.1**[a] | 26.8 | **67.9**[a] | 33.9 | **67.9**[a] | 58.9 | **73.2**[a] |
| 9 | 2 | **68.8**[a] | **89.6**[a] | 59.3 | 14.8 | **93.75**[a] | **83.3**[a] | **77.1**[a] | 27.1 | 35.4 | 27.8 | 59.3 | 33.3 | **83.3**[a] | 35.4 | 33.3 | 43.8 | 55.6 | 38.9 | 64.6 | 52.1 | 35.4 |
| 10 | 3 | **80.6**[a] | **75.0**[a] | 44.4 | **100.0**[a] | **88.89**[a] | **75.0**[a] | **83.3**[a] | 50 | **79.6**[a] | 55.6 | 27.8 | 51.9 | 33.3 | 44.4 | 11.1 | 16.7 | 2.8 | 52.8 | 33.3 | 25.0 | 13.9 |
| 11 | 3 | **90.0**[a] | 61.7 | **78.3**[a] | **70.0**[a] | 60.0 | 61.7 | **73.3**[a] | 33.3 | 53.3 | 43.4 | **95**[a] | 51.7 | 55 | **75.0**[a] | 35.0 | 35.0 | 55.0 | 55.0 | 32.5 | 15.0 | **70.0**[a] |
| 12 | 2 | **85.2**[a] | 27.8 | **66.7**[a] | 44.4 | **75.93**[a] | **70.4**[a] | **77.8**[a] | **88.9**[a] | **74.1**[a] | **77.8**[a] | 0.0 | **85.2**[a] | 64.8 | **81.5**[a] | **88.9**[a] | 24.1 | 44.4 | 16.7 | 61.1 | 59.3 | **77.8**[a] |
| 13 | 3 | **81.3**[a] | **66.7**[a] | **85.4**[a] | 53.3 | **79.17**[a] | **93.8**[a] | **72.9**[a] | 43.8 | 47.9 | 56.3 | 60.0 | 39.6 | 41.7 | 50.0 | 9.4 | 40.6 | 37.5 | 22.5 | 40.6 | 21.9 | 6.3 |
| 14 | 2 | **66.7**[a] | 41.7 | 56.3 | **66.7**[a] | **89.58**[a] | **81.3**[a] | 45.8 | 52.1 | 43.8 | 47.9 | 57.4 | 52.1 | 45.8 | 47.9 | 37.5 | 8.3 | 31.3 | 35.2 | 29.2 | 45.8 | 25.0 |
| 15 | 1 | **87.5**[a] | 58.3 | 56.3 | **75.0**[a] | 54.17 | 50.0 | **77.1**[a] | **100**[a] | 54.2 | **79.2**[a] | 58.3 | 64.6 | **79.2**[a] | **75.0**[a] | **84.4**[a] | 53.1 | **76.6**[a] | 64.1 | 31.3 | 39.1 | **82.8**[a] |
| 16 | 3 | 46.7 | **71.7**[a] | 60.0 | 43.3 | 65.0 | **76.7**[a] | **76.7**[a] | 63.3 | 65.0 | 60.0 | 11.7 | 55.0 | 63.3 | **70.0**[a] | 30.0 | 30.0 | 60.0 | 0.0 | 20.0 | 50.0 | 37.5 |
| 17 | 1 | **93.8**[a] | **81.3**[a] | **87.5**[a] | **100**[a] | **70.83**[a] | 35.4 | **81.3**[a] | 37.5 | 50.0 | 45.8 | **70.8**[a] | 18.8 | 6.3 | 29.2 | 15.6 | 40.6 | 18.8 | 32.8 | 18.8 | 6.3 | 20.3 |
| 18 | 2 | 50.0 | 50.0 | 61.1 | 55.6 | 41.67 | 22.2 | **66.7**[a] | 50.0 | **77.8**[a] | **77.8**[a] | **97.2**[a] | 16.7 | 8.3 | **66.7**[a] | 50.0 | 61.1 | **66.7**[a] | 41.7 | 30.6 | 22.2 | 61.1 |
| Moderate-to-large effect | | 13/18 | 9/18 | 8/18 | 7/18 | 11/18 | 12/18 | 12/18 | 4/18 | 4/18 | 5/18 | 4/18 | 3/18 | 3/18 | 6/18 | 3/18 | 1/18 | 5/18 | 3/18 | 3/18 | 0/18 | 5/18 |

Bold data indicates that the result is statistically significant.
[a] Moderate-to-large effect (NAP indices >66).

improvements in at least one outcome measure in almost all participants. More specifically, the variables associated with positive emotional states and their regulation (i.e., PA, memory vividness, frequency of positive reminiscence and savoring) presented a moderate-to-large improvement in more than half of the participants, which is coherent with our hypotheses. By contrast, the number of individuals showing a significant gain on negatively valenced measures (i.e., NA, rumination and depressive symptoms) was lower. The results are consistent with the idea that PA and NA do not lie on two opposite ends of a bipolar scale; instead, they can be experienced simultaneously (Berrios et al., 2015; Larsen and McGraw, 2011). Thus, the smaller effect on negatively valenced outcome measures might be the consequence of the intrinsic nature of the intervention, which was meant to target the recall of positive memories and, therefore, the enhancement of positive emotions. However, the more modest changes on negatively valenced variables should not be ignored. Half of the participants reported a moderate-to-large improvement in NA levels. Previous research has already shown that positive and negative induction procedures have the potential to lead to an activation of the other dimension (Joseph et al., 2020), thus suggesting that the elicitation of positive emotions through VR may indirectly target and reduce also negative affective states. Furthermore, it is important to note that we did not observe the expected improvements on daily rumination levels, as only 7 out of 18 participants reported a moderate-to-large significant effect in this variable. A possible explanation may rely on the design of the study. The intervention consisted of two sessions provided on two consecutive days, which might have reduced the consolidation and practice of the learned skills. As the protocol was not designed to directly target rumination, more sessions provided over a longer period of time could have been needed to reduce the likelihood of ruminative thinking.

Interestingly, the participants who improved in one variable were also likely to get better in other outcome measures, including mechanisms that are argued to underlie depressive symptoms like emotion regulation skills (Sloan et al., 2017), which confirms the strong association among memory, affect, and emotion regulation (Dalgleish and Werner-Seidler, 2014). Furthermore, participants who were less responsive to the treatment were generally more likely to report higher baseline PA and lower baseline NA. Recent studies have also reported that individuals with high PA/extraversion and low NA/neuroticism are less likely to benefit from a psychological intervention, in this case a 12-week transdiagnostic treatment (Osma et al., 2021). In other words, what the aforementioned study and the current investigation suggest is that there might be less room for improvement in persons with a more adaptive affective profile at baseline. This observation might be important for personalized therapy and suggests that the present VR-based protocol (and potentially other psychological interventions for emotional problems) might be more beneficial for individuals who experience low PA and high NA levels.

To resume, the results of the present study do not support the efficacy of our VR intervention to produce enduring changes in key clinical outcomes in moderate-to-moderately severe depressed individuals. In contrast to this idea, almost all participants reported moderate-to-large improvements in at least one positively-valenced variable in the very short term, while more modest changes on negatively valenced outcomes were found. Together, these findings support the utility of the VR-based AM recall task to obtain immediate and/or brief-term improvements in individuals with moderate-to-moderately severe depression. Thus, this might be a therapeutic component that could potentially be integrated in a broader treatment protocol for mild depression.

Despite these interesting findings, this study is not free of limitations. First, the VR procedure was only implemented twice, and sessions were provided on two consecutive days. Therefore, the extent to which the short-term effects of the current treatment can be maintained or even improved with repeated practice over time remains unclear. A recent meta-analysis showed that AM interventions usually include between 4 and 8 sessions (Ahmadi Forooshani et al., 2020). Similar to the present study findings, this meta-analysis supported the efficacy of such brief treatments on memory specificity, but also indicated that these interventions are not be recommendable as stand-alone treatments. Based on these findings, it is not surprising that our results could only reveal short-term effects. While this might be seen as a limitation of the investigation, the fact that short-term changes occurred with two sessions only could also be viewed as a promising finding, suggesting that this easy-to-implement procedure might be an adequate therapeutic option for short-term positive mood induction. However, it would be of utmost importance to consider how the task could be integrated in a broader protocol of intervention, as well as explore the benefits of using this procedure as a just-on time intervention. In this sense, the usability and acceptability for this technology use were not explored, which would be important for implementation purposes. Besides, the nature of our sample might constitute a further limitation of the study. One the one hand, the sample was composed of individuals with moderate-to-moderately severe depressive symptoms. However, most of the participants was likely to shown moderate symptoms, according to the PHQ-9 scores assessed at the baseline. The extent to which this intervention might be beneficial for patients with more severe depressive conditions remains an open question. On the other hand, recruiting a bigger sample would permit to explore moderators of treatment response (i.e., communalities between responders and non-responders to the intervention), mediators of change (i.e., the mechanisms explaining why individuals change with the treatment), and how the variables investigated in this study reciprocally influenced each other in order to produce a change (cross-lagged analysis). Finally, the findings of the present study might have been influenced by the specific design of the protocol. For instance, the mood ratings administered during the VR sessions (i.e., manipulation check) might have affected the scores of daily PA and NA collected at the end of the same day. Furthermore, although moderate improvements were observed in positive emotion regulation measures such as savoring and positive reminiscence, these results might have been affected by the significant enhancement of daily PA. In other words, a more positive mood throughout the day might have produced higher scores on these items. To this end, more research is needed to understand the mechanisms of change underlying this intervention. Even though this type of design might have somehow influenced the results, the selection of a SCED and the adherence to the SCRIBE guidelines should actually be considered as a strength of the present investigation, which might inspire future studies in the field.

## 5. Conclusions

To conclude, the VR-based procedure presented in the current study seems to be a promising tool to induce positive mood and enhance positive emotion regulation strategies in the short term. Although our study only included participants with moderate-to-moderately severe depressive symptoms, which limits the generalizability of findings to patients with more severe depressive conditions, the proposed procedure could potentially be included as a clinically relevant component within a broader intervention protocol. Importantly, even though our study adopted a more sophisticated head-mounted display (i.e., Oculus Rift), the mobile application *Google Earth* has been recently developed both for Android and IOS systems. In other words, the VR-based AM task proposed in the present research could potentially be performed outside face-to-face therapeutic settings, thus representing a rapid self-help procedure to be used by patients in daily life. Additionally, note that our study focused on the past and, more specifically, on the use of VR to provide a spatial reference while recalling positive memories. However, the same procedure could potentially be applied to the future: that is, to provide a virtual spatial reference in which to anticipate positive events or make plans. Considering the association between negatively biased affective forecasting and depression (Colombo et al., 2020a, 2020b), virtually travelling to the future and anticipating positive experiences might represent a useful therapeutic tool to enhance one's optimism,

motivation and openness to the future (Botella et al., 2018). In this direction, a recent study has revealed the feasibility and efficacy of VR as a method to administer behavioural activation for depression (Paul et al., 2020). Similarly, anticipating either brief- (e.g., going out for a walk in the park) or long-terms future positive events (e.g., planning a trip to New York) by virtually travelling to the associated place might represent a valid approach to encourage behavioural activation in patients suffering from depression.

Despite some lessons have been learnt, more research is still needed to explore the potentiality of this and similar interventions in routine care.

## Funding

This work was supported by the Marie Curie EF-ST AffecTech Project, approved at call H2020 – MSCA – ITN – 2016, under grant number 722022.

## Declaration of competing interest

The authors declare that there is no conflict of interest.

## References

Ahmadi Forooshani, S., Murray, K., Izadikhah, Z., Khawaja, N., 2020. Identifying the most effective strategies for improving autobiographical memory specificity and its implications for mental health problems: a meta-analysis. Cognit. Ther. Res. 44, 258–274. https://doi.org/10.1007/s10608-019-10061-8.

Aldao, A., Jazaieri, H., Goldin, P.R., Gross, J.J., 2014. Adaptive and maladaptive emotion regulation strategies: interactive effects during CBT for social anxiety disorder. J. Anxiety Disord. 28, 382–389. https://doi.org/10.1016/j.janxdis.2014.03.005.

Angermeyer, M.C., Holzinger, A., Matschinger, H., Stengler-Wenzke, K., 2002. Depression and quality of life: results of a follow-up study. Int. J. Soc. Psychiatry 48, 189–199. https://doi.org/10.1177/002076402128783235.

Baños, R.M., Botella, C., Alcañiz, M., Liaño, V., Guerrero, B., Rey, B., 2004. Immersion and emotion: their impact on the sense of presence. Cyberpsychol. Behav. 7, 734–741. https://doi.org/10.1089/cpb.2004.7.734.

Baños, R.M., Botella, C., Rubió, I., Quero, S., García-Palacios, A., Alcañiz, M., 2008. Presence and emotions in virtual environments: the influence of stereoscopy. Cyberpsychol. Behav. 11, 1–8. https://doi.org/10.1089/cpb.2007.9936.

Bauer, A.M., Baldwin, S.A., Anguera, J.A., Areán, P.A., Atkins, D.C., 2018. Comparing approaches to mobile depression assessment for measurement-based care: prospective study. J. Med. Internet Res. https://doi.org/10.2196/10001.

Beck, A.T., Haigh, E.A.P., 2014. Advances in cognitive theory and therapy: the generic cognitive model. Annu. Rev. Clin. Psychol. 10, 1–24. https://doi.org/10.1146/annurev-clinpsy-032813-153734.

Berrios, R., Totterdell, P., Kellett, S., 2015. Investigating goal conflict as a source of mixed emotions. Cognit. Emot. https://doi.org/10.1080/02699931.2014.939948.

Botella, C., Villa, H., García-Palacios, A., Baños, R.M., Perpiñá, C., Alcañiz, M., 2004. Clinically significant virtual environments for the treatment of panic disorder and agoraphobia. Cyberpsychol. Behav. 7, 527–535. https://doi.org/10.1089/cpb.2004.7.527.

Botella, C., Fernández-Álvarez, J., Guillen, V., Garcia-Palacios, A., Banos, R., Fernández-Álvarez, J., Guillén, V., García-Palacios, A., Baños, R., 2017. Recent progress in virtual reality exposure therapy for phobias: a systematic review. Curr. Psychiatry Rep. 19, 42. https://doi.org/10.1007/s11920-017-0788-4.

Botella, C., Molinari, G., Fernández-Álvarez, J., Guillén, V., García-Palacios, A., Baños, R. M., Tomás, J.M., 2018. Development and validation of the openness to the future scale: a prospective protective factor. Health Qual. Life Outcomes 16, 1–16. https://doi.org/10.1186/s12955-018-0889-8.

Brewer, W.F., 1994. Autobiographical memory and survey research. In: Autobiographical Memory and the Validity of Retrospective Reports, pp. 11–20. https://doi.org/10.1007/978-1-4612-2624-6_2.

Bryant, F.B., Smart, C.M., King, S.P., 2005. Using the past to enhance the present: boosting happiness through positive reminiscence. J. Happiness Stud. 6, 227–260. https://doi.org/10.1007/s10902-005-3889-4.

Burt, D.B., Zembar, M.J., Niederehe, G., 1995. Depression and memory impairment: a meta-analysis of the association, its pattern, and specificity. Psychol. Bull. 117, 285. https://doi.org/10.1037/0033-2909.117.2.285.

Carl, E., Stein, A.T., Levihn-Coon, A., Pogue, J.R., Rothbaum, B., Emmelkamp, P., Asmundson, G.J.G., Carlbring, P., Powers, M.B., 2019. Virtual reality exposure therapy for anxiety and related disorders: a meta-analysis of randomized controlled trials. J. Anxiety Disord. 61, 27–36. https://doi.org/10.1016/j.janxdis.2018.08.003.

Colombo, D., Suso-Ribera, C., Fernández-Álvarez, J., Fernández-Felipe, I., Cipresso, P., Garcia-Palacios, A., Riva, G., Botella, C., 2019. Exploring affect recall bias and the impact of mild depressive symptoms: an ecological momentary study. In: Pervasive Computing Paradigms for Mental Health. Springer, pp. 208–215.

Colombo, Desiree, Fernández-Álvarez, J., Suso-Ribera, C., Cipresso, P., Garcia-Palacios, A., Riva, G., Botella, C., 2020a. Biased affective forecasting: a potential mechanism that enhances resilience and well-being. Front. Psychol. 11 https://doi.org/10.3389/fpsyg.2020.01333.

Colombo, Desirée, Suso-Ribera, C., Fernández Álvarez, J., Cipresso, P., Garcia-Palacios, A., Riva, G., Botella, C., 2020b. Affect recall bias: being resilient by distorting reality. Cognit. Ther. Res. 1–13.

Conway, M.A., 1987. Verifying autobiographical facts. Cognition 26, 39–58. https://doi.org/10.1016/0010-0277(87)90013-8.

Dalgleish, T., Werner-Seidler, A., 2014. Disruptions in autobiographical memory processing in depression and the emergence of memory therapeutics. Trends Cogn. Sci. 18, 596–604. https://doi.org/10.1016/j.tics.2014.06.010.

De Vos, S., Wardenaar, K.J., Bos, E.H., Wit, E.C., Bouwmans, M.E.J., De Jonge, P., 2017. An investigation of emotion dynamics in major depressive disorder patients and healthy persons using sparse longitudinal networks. PLoS One 12, e0178586. https://doi.org/10.1371/journal.pone.0178586.

Diez-Quevedo, C., Rangil, T., Sanchez-Planell, L., Kroenke, K., Spitzer, R.L., 2001. Validation and utility of the patient health questionnaire in diagnosing mental disorders in 1003 general hospital Spanish inpatients. Psychosom. Med. 63, 679–686. https://doi.org/10.1097/00006842-200107000-00021.

Falconer, C.J., Rovira, A., King, J.A., Gilbert, P., Antley, A., Fearon, P., Ralph, N., Slater, M., Brewin, C.R., 2016. Embodying self-compassion within virtual reality and its effects on patients with depression. BJPsych Open 2, 74–80. https://doi.org/10.1192/bjpo.bp.115.002147.

Ferrando, L., Soto, M., Bobes, J., Soto, O., Franco, L., Gibert, J., 2000. Mini international neuropsychiatric interview (Spanish version 5.0). Institute IAP, Madrid.

Gaddy, M.A., Ingram, R.E., 2014. A meta-analytic review of mood-congruent implicit memory in depressed mood. Clin. Psychol. Rev. 34, 402–416. https://doi.org/10.1016/j.cpr.2014.06.001.

Gómez-Pérez, M.C., García-Palacios, A., Diana, C., Zaragozá, I., Suso-Ribera, C., 2020. Brief acceptance and commitment therapy for. feasibility and effectiveness of a replicated single-case design. Pain Res. Manag, fibromyalgia. https://doi.org/10.1155/2020/7897268.

Gotlib, I.H., Joormann, J., 2010. Cognition and depression: current status and future directions. Annu. Rev. Clin. Psychol. 6, 285–312. https://doi.org/10.1146/annurev.clinpsy.121208.131305.

Hirschfeld, R.M.A., Montgomery, S.A., Keller, M.B., Kasper, S., Schatzberg, A.F., Möller, H.J., Healy, D., Baldwin, D., Humble, M., Versiani, M., Montenegro, R., Bourgeois, M., 2000. Social functioning in depression: a review. J. Clin. Psychiatry. https://doi.org/10.4088/JCP.v61n0405.

Jallais, C., Gilet, A.-L., 2010. Inducing changes in arousal and valence: comparison of two mood induction procedures. Behav. Res. Methods 42, 318–325. https://doi.org/10.3758/BRM.42.1.318.

Joseph, D.L., Chan, M.Y., Heintzelman, S.J., Tay, L., Diener, E., Scotney, V.S., 2020. The manipulation of affect: a meta-analysis of affect induction procedures. Psychol. Bull. 146, 355. https://doi.org/10.1037/bul0000224.

Kazdin, A.E., 2011. Single-case Research Designs: Methods for Clinical and Applied Settings, 2nd ed.

Klein, S.B., 2015. What memory is. Wiley Interdiscip. Rev. Cogn. Sci. 6, 1–38. https://doi.org/10.1002/wcs.1333.

Kratochwill, T.R., Hitchcock, J., Horner, R.H., Levin, J.R., Odom, S.L., Rindskopf, D.M., Shadish, W.R., 2010. Single-case Designs Technical Documentation. Clearinghouse, What Works ((ED), W.W.C.).

Kratochwill, T.R., Hitchcock, J.H., Horner, R.H., Levin, J.R., Odom, S.L., Rindskopf, D. M., Shadish, W.R., 2013. Single-case intervention research design standards. Remedial Spec. Educ. 34, 26–38. https://doi.org/10.1177/0741932512452794.

Kroenke, K., Spitzer, R.L., Williams, J.B.W., 2001. The PHQ-9: validity of a brief depression severity measure. J. Gen. Intern. Med. 16, 606–613. https://doi.org/10.1046/j.1525-1497.2001.016009606.x.

Kroenke, K., Spitzer, R.L., Williams, J.B.W., 2003. The patient health questionnaire-2: validity of a two-item depression screener. Med. Care 1284–1292. https://doi.org/10.1097/01.MLR.0000093487.78664.3C.

Larsen, J.T., McGraw, A.P., 2011. Further evidence for mixed emotions. J. Pers. Soc. Psychol. https://doi.org/10.1037/a0021846.

Lemogne, C., Piolino, P., Friszer, S., Claret, A., Girault, N., Jouvent, R., Allilaire, J.F., Fossati, P., 2006. Episodic autobiographical memory in depression: specificity, autonoetic consciousness, and self-perspective. Conscious. Cogn. 15, 258–268. https://doi.org/10.1016/j.concog.2005.07.005.

Lindner, P., Miloff, A., Fagernäs, S., Andersen, J., Sigeman, M., Andersson, G., Furmark, T., Carlbring, P., 2019. Therapist-led and self-led one-session virtual reality exposure therapy for public speaking anxiety with consumer hardware and software: a randomized controlled trial. J. Anxiety Disord. 61, 45–54. https://doi.org/10.1016/j.janxdis.2018.07.003.

Matt, G.E., Vázquez, C., Campbell, W.K., 1992. Mood-congruent recall of affectively toned stimuli: a meta-analytic review. Clin. Psychol. Rev. 12, 227–255. https://doi.org/10.1016/0272-7358(92)90116-P.

Migoya-Borja, M., Delgado-Gómez, D., Carmona-Camacho, R., Porras-Segovia, A., López-Moriñigo, J.D., Sánchez-Alonso, M., Albarracín García, L., Guerra, N., Barrigón, M. L., Alegría, M., Baca-García, E., 2020. Feasibility of a virtual reality-based psychoeducational tool (VRight) for depressive patients. Cyberpsychol. Behav. Soc. Netw. 23, 246–252. https://doi.org/10.1089/cyber.2019.0497.

Neshat-Doost, H.T., Taghavi, M.R., Moradi, A.R., Yule, W., Dalgleish, T., 1998. Memory for emotional trait adjectives in clinically depressed youth. J. Abnorm. Psychol. 107, 642–650. https://doi.org/10.1037/0021-843X.107.4.642.

Osma, J., Peris-Baquero, O., Suso-Ribera, C., Sauer-Zavala, S., Barlow, D.H., 2021. Predicting and moderating the response to the unified protocol: do baseline personality and affective profiles matter? Cognit. Ther. Res. https://doi.org/10.1007/s10608-021-10208-6.

Parker, R.I., Vannest, K.J., Davis, J.L., 2011. Effect size in single-case research: a review of nine nonoverlap techniques. Behav. Modif. 35, 303–322. https://doi.org/10.1177/0145445511399147.

Parker, R.I., Vannest, K.J., Davis, J.L., 2014. Non-overlap analysis for single-case research. In: Single-case Intervention Research: Methodological and Statistical Advances. https://doi.org/10.1037/14376-005.

Pascuzzi, D., Smorti, A., 2017. Emotion regulation, autobiographical memories and life narratives. New Ideas Psychol. 45, 28–37. https://doi.org/10.1016/j.newideapsych.2016.12.001.

Paul, M., Bullock, K., Bailenson, J., 2020. Case report: virtual reality behavioral activation as an intervention for major depressive disorder. JMIR Ment. Health 7. https://doi.org/10.2196/24331.

Quoidbach, J., Berry, E.V., Hansenne, M., Mikolajczak, M., 2010. Positive emotion regulation and well-being: comparing the impact of eight savoring and dampening strategies. Personal. Individ. Differ. 49, 368–373. https://doi.org/10.1016/j.paid.2010.03.048.

Quoidbach, J., Mikolajczak, M., Gross, J.J., 2015. Positive interventions: an emotion regulation perspective. Psychol. Bull. 141, 655. https://doi.org/10.1037/a0038648.

Romano, M., Moscovitch, D.A., Huppert, J.D., Reimer, S.G., Moscovitch, M., 2020. The effects of imagery rescripting on memory outcomes in social anxiety disorder. J. Anxiety Disord. 69, 102–169. https://doi.org/10.1016/j.janxdis.2019.102169.

Shah, L.B.I., Torres, S., Kannusamy, P., Chng, C.M.L., He, H.G., Klainin-Yobas, P., 2015. Efficacy of the virtual reality-based stress management program on stress-related variables in people with mood disorders: the feasibility study. Arch. Psychiatr. Nurs. 29, 6–13. https://doi.org/10.1016/j.apnu.2014.09.003.

Siedlecki, K.L., 2015. Visual perspective in autobiographical memories: reliability, consistency, and relationship to objective memory performance. Memory 23, 306–316. https://doi.org/10.1080/09658211.2014.885054.

Sloan, E., Hall, K., Moulding, R., Bryce, S., Mildred, H., Staiger, P.K., 2017. Emotion regulation as a transdiagnostic treatment construct across anxiety, depression, substance, eating and borderline personality disorders: a systematic review. Clin. Psychol. Rev. 57, 141–163. https://doi.org/10.1016/j.cpr.2017.09.002.

Strack, F., Schwarz, N., Gschneidinger, E., 1985. Happiness and reminiscing: the role of time perspective, affect, and mode of thinking. J. Pers. Soc. Psychol. 49, 1460–1469. https://doi.org/10.1037/0022-3514.49.6.1460.

Sumner, J.A., Griffith, J.W., Mineka, S., 2010. Overgeneral autobiographical memory as a predictor of the course of depression: a meta-analysis. Behav. Res. Ther. 48, 614–625. https://doi.org/10.1016/j.brat.2010.03.013.

Suso-Ribera, C., Castilla, D., Zaragozá, I., Ribera-Canudas, M.V., Botella, C., García-Palacios, A., 2018. Validity, reliability, feasibility, and usefulness of pain monitor, a multidimensional smartphone app for daily monitoring of adults with heterogeneous chronic pain. Clin. J. Pain 34, 1. https://doi.org/10.1097/AJP.0000000000000618.

Tate, R.L., Perdices, M., Rosenkoetter, U., Shadish, W., Vohra, S., Barlow, D., Horner, R., Kazdin, A., Kratochwill, T., McDonald, S., Sampson, M., Shamseer, L., Togher, L., Albin, R., Backman, C., Douglas, J., Evans, J.J., Gast, D., Manolov, R., Mitchell, G., Nickels, L., Nikles, J., Ownsworth, T., Rose, M., Schmid, C.H., Wilson, B., 2016. The Single-Case Reporting Guideline In BEhavioural interventions (SCRIBE) 2016 statement. Remedial Spec. Educ. 37, 370–380. https://doi.org/10.1177/0741932516652893.

Wallace-Hadrill, S.M.A., Kamboj, S.K., 2016. The impact of perspective change as a cognitive reappraisal strategy on affect: a systematic review. Front. Psychol. https://doi.org/10.3389/fpsyg.2016.01715.

Watkins, E., Teasdale, J.D., 2001. Rumination and overgeneral memory in depression: effects of self-focus and analytic thinking. J. Abnorm. Psychol. 110, 353–357. https://doi.org/10.1037/0021-843X.110.2.333.

Williams, J.M.G., Barnhofer, T., Crane, C., Herman, D., Raes, F., Watkins, E., Dalgleish, T., 2007. Autobiographical memory specificity and emotional disorder. Psychol. Bull. 133, 122. https://doi.org/10.1037/0033-2909.133.1.122.

Wittchen, H.U., Jacobi, F., Rehm, J., Gustavsson, A., Svensson, M., Jönsson, B., Olesen, J., Allgulander, C., Alonso, J., Faravelli, C., Fratiglioni, L., Jennum, P., Lieb, R., Maercker, A., van Os, J., Preisig, M., Salvador-Carulla, L., Simon, R., Steinhausen, H.C., 2011. The size and burden of mental disorders and other disorders of the brain in Europe 2010. Eur. Neuropsychopharmacol. 21, 655–679. https://doi.org/10.1016/j.euroneuro.2011.07.018.

Zeng, N., Pope, Z., Lee, J., Gao, Z., 2018. Virtual reality exercise for anxiety and depression: a preliminary review of current research in an emerging field. J. Clin. Med. 7, 42. https://doi.org/10.3390/jcm7030042.

Zhang, X., Yu, H.W., Barrett, L.F., 2014. How does this make you feel? A comparison of four affect induction procedures. Front. Psychol. 5, 689. https://doi.org/10.3389/fpsyg.2014.00689.