Acta Psychologica 266 (2026) 106912

Contents lists available at ScienceDirect

Acta Psychologica

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

Exploring the use of virtual reality for episodic future thinking☆

Simon T. van Baal[a,b,*], Verity Petratos[c], Arnaud Prouzeau[d], Adélaïde Genay[e], Antonio Verdejo-García[c]

[a] Analytics, Technology, and Operations Department, Leeds University Business School, University of Leeds, Charles Thackrah Building, 90 Clarendon Road, Leeds, LS29JT, United Kingdom

[b] Department of Psychology, University of Warwick, Coventry, CV47AL, United Kingdom

[c] School of Psychological Sciences & Turner Institute for Brain and Mental Health, Monash University, 18 Innovation Walk, 3800, Clayton, VIC, Australia

[d] Université Paris-Saclay, Inria, CNRS, Paris, France

[e] School of Computing and Information Systems, University of Melbourne, Parkville, VIC, Australia

ARTICLE INFO

Keywords:
Episodic future thinking
Virtual reality
Delay discounting
Intertemporal choice
Present bias

ABSTRACT

Undervaluing future rewards is a significant problem that leads to issues like addiction and eating disorders. Episodic future thinking (EFT), which involves imagining future experiences, can help mitigate these problems by increasing the perceived value of future rewards. However, not everyone can perform EFT as it requires imagination and sustained mental effort. To address this, we propose using Virtual Reality (VR) to simulate future scenarios and help people perform EFT. In a study, we compared a VR experience designed to elicit EFT to a control experience and measured participants' preferences for future rewards using an inter-temporal choice task. We also estimated their present bias and time-sensitive devaluation. Although the results were inconclusive, our sample showed indications that the VR-based EFT protocol may effectively decrease present bias, time-sensitive devaluation, and preference reversals. Overall, our preliminary results suggest that VR could be a viable method for facilitating EFT.

1. Introduction

Behavioural addictions such as gambling and internet gaming disorders involve persistent selection of options favouring immediate reward at the potential cost of long-term losses (Ioannidis et al., 2019; Lawrence et al., 2009; Potenza et al., 2019). This pattern of behaviour resembles steep delay discounting, a common way of measuring and expressing a preference for small immediate rewards over larger but delayed ones (van Baal et al., 2025). Although steeper discounting rates, indicated by delay discounting measures, are transdiagnostically associated with different addictive disorders (Amlung et al., 2019), evidence suggest these alterations are particularly prominent among people with behavioural addictions (Albein-Urios et al., 2014). Furthermore, theoretical and computational frameworks suggest that steeper delay discounting is mechanistically implicated in behavioural addictions' psychopathology and thus qualifies as a prime treatment target (Kalhan et al., 2023; Kayser, 2019). Despite its prominence, few studies test specific delay discounting interventions in behavioural addictions (Verdejo-García et al., 2019).

A highly promising intervention to change delay discounting and related excessive reward-driven behaviours is Episodic Future Thinking (EFT). EFT is a procedure in which people are instructed to mentally visualise a future autobiographical experience using past information from their episodic memory (i.e., the collection of past personal experiences; Schacter et al., 2017). It provides the opportunity to learn from hypothetical events by imagining novel or future scenarios, and direct behaviour towards achieving long-term goals (Szpunar, 2010). The subsequent feelings, emotions, and sensations that arise from vividly imagining a future event can motivate behaviour change with greater consideration of long-term consequences (Rung et al., 2018; Segovia et al., 2020). Accordingly, EFT has been found to decrease the degree to which individuals discount future outcomes in intertemporal choice paradigms (mean Hedges $g = 0.38$, Göllner et al., 2018; Rung et al., 2018; Rung & Madden, 2018). Emerging evidence suggests that EFT can leverage its impact on delay discounting to change real-world behaviours, including reducing consumption of energy-dense foods, alcohol and cigarette in hypothetical, laboratory, and real-life settings (Bulley & Gullo, 2017; O'Neill et al., 2016; Stein et al., 2018).

☆ This article is part of a Special issue entitled: 'BA intervention/prevention' published in Acta Psychologica.

* Corresponding author at: Charles Thackrah Building, 90 Clarendon Road, University of Leeds, Leeds, LS29JT, United Kingdom.
E-mail address: s.t.vanbaal@leeds.ac.uk (S.T. van Baal).

https://doi.org/10.1016/j.actpsy.2026.106912
Received 22 October 2025; Received in revised form 16 February 2026; Accepted 20 April 2026
Available online 2 May 2026

Traditionally, EFT is elicited through guided scene construction or internal cueing methods where individuals generate personalized future events (Stein et al., 2017). In the guided scene construction method, participants are prompted to describe details of the event as if it were currently occurring. They are also asked to consider how they feel to increase their emotional arousal during the imagined scenario and make it more vivid and attractive (Schacter et al., 2017). Similarly, the cueing words method involves instructing individuals to evoke and describe positive and realistic future events that are subsequently used by instructors to prompt mental representations of future events during EFT (J. M. Brown & Stein, 2022; Hallford et al., 2018). However, individuals with external locus of control, arousal dysregulation, or difficulties shifting away from cached sets of mental imagery (e.g. gambling and gaming cues), all of which feature in behavioural addictions, can have trouble achieving EFT through these methods (Hallford et al., 2018; Race et al., 2011; Sun et al., 2023). Overall, there is consistent evidence that populations with psychopathologies generate less specific and detailed episodic future events (Hallford et al., 2018), thus compromising the potential therapeutic efficacy of EFT.

Virtual Reality (VR) is optimally suited as an alternative approach to help elicit EFT in people with behavioural addictions. VR can assist these individuals in imagining how they may act and feel in hypothetical future environments by taking away some of the mental effort required to generate these positive and realistic scenarios and compensating for some of their specific cognitive and affective limitations (T. Brown et al., 2020). Indeed, emerging evidence suggests that VR can be effectively used to generate complex and vivid future memories (Wang et al., 2019). Notably, Friedman et al. (2014) found that participants could experience the "illusion of time travel" through repeated experiences of a fictional event over a VR simulation. Another promising study by Habak et al. (2021) used VR simulations of landscapes in combination with an interactive room to elicit positive thoughts about the future. The authors speculated that the reduction in hopelessness would coincide with increased positive future thinking and thus greater sensitivity to future rewards.

Paving the way for future research on VR-based EFT protocols, this pilot study presents an interactive and immersive VR experience to facilitate EFT. To this end, we developed a simulation that immerses participants in the Kokoda Track Memorial Walk (informally known as 1000 Steps Walk)—a popular walk near Melbourne, Australia—to assist them in visualising a future positive scenario in the same location. To evaluate whether our VR-based protocol is a viable method for facilitating EFT, we measured the degree to which healthy participants discounted future rewards after the EFT simulation and compared these responses to those after a non-EFT VR simulation. A focus on healthy participants is appropriate given the lack of previous research using this approach in clinical populations with behavioural addictions (making this study a phase 0 intervention study). We adopted a specific instance of delay discounting as outcome measure. Specifically, we assumed that people discount future rewards according to the quasi-hyperbolic discounting model (Laibson, 1997). Unlike the hyperbolic model (Ainslie, 1975; Loewenstein & Thaler, 1989; Mazur, 1987), the quasi-hyperbolic model allows us to dissociate *present bias* from *time-sensitive devaluation* of outcomes. This is relevant because present bias, where people devalue outcomes when they are not immediate, causes *preference reversals*—-people prefer long-term outcomes (e.g., health) but sometimes succumb to short-term temptation (e.g., fast-food)—which has been theorised to underlie harmful behaviour patterns in, for example, drug dependence (Bickel & Marsch, 2001).

The current paper is the first to present a user study investigating the potential of VR-based EFT in attenuating present bias, preference reversals, and time-sensitive devaluation in healthy controls. This will indicate whether delay discounting may be attenuated using a VR-based EFT protocol in people with behavioural addictions, and thus if it could be a promising avenue for clinical trials research.

2. Methods

2.1. Design

We conducted a user study comparing two conditions: (i) an experimental condition where participants were asked to perform EFT within a VR simulation of an imagined future, and (ii) a control condition where they were simply immersed in an arbitrary VR environment without being instructed to perform EFT. The participants engaged in two sessions (one per condition) in counterbalanced order, conducted a minimum of three weeks apart to minimise carryover effects.

To simulate a plausible positive future experience for the participants in the EFT condition, we recreated a real-world location in VR (the Kokoda Track Memorial Walk in Melbourne, Australia) and only recruited local participants who had visited the location before. This allowed participants to use their own memories of the location to generate the EFT experience, but with support from the VR scenario to minimise cueing and imagery demands. For the control condition, we used an off-the-shelf environment that we knew would not encourage EFT (a solar system representation). Before being immersed in either of these environments, the participants were subjected to a training simulation to familiarise themselves with VR and learn how to navigate in the virtual environment using teleportation. Our study was preregistered on the Open Science Foundation platform, and the questionnaires used are available there (https://osf.io/zabke/?view_only=7bbe4a66eabb4817b1ed2488a71e3c00).

2.2. Participants

We recruited 24 participants through volunteer sampling with social media posts that advertised the study. We excluded two of these; one failed the manipulation checks (we asked them: "what did you see?"; if they did not mention anything related to the simulation, they were excluded), and another spent an abnormal amount of time in a simulation (15 min). The final sample consisted of a total of 22 participants: seven males aged 19–48 years ($M = 32.86$, $SD = 11.71$), 14 females aged 21–48 years ($M = 29.71$, $SD = 8.90$) and one person who chose not to disclose their gender.

Sample size was calculated using simulations replicating our Bayesian analysis (see more below). The posterior predictive density was half the effect size, allowing for a good initial test of the hypotheses.

2.3. Interactive scenes

For the simulations, we used an HP Windows Reverb Mixed Virtual Reality headset (90hz, 2160 × 2160 pixels per eye), running on a Dell Precision 7540. A workstation laptop with an Intel Core i7-9850H CPU @ 2.60GHz 2.59 processor was used for the two interactive scenes used in the experiment: VR-Episodic Future Thinking (EFT) and Control.

2.3.1. VR-Episodic Future Thinking

To assist participants in evoking a future positive event we created a VR simulation of the Kokoda Track Memorial Walk, a popular recreational track in Melbourne (the city where the study took place). The Kokoda Track Memorial Walk interactive experience consisted of 3 scenes showing the beginning of the walk, a section in the middle, and the top.[1] Google Streetview 360 pictures were used to model for manual recreation of dynamic "scenes" during the hike using the Unity Terrain module (See 1-Top for the first scene and Supplementary Material for the others). We added fictional characters who conversed in the background using recorded conversations and an audio atmosphere (i.e., birds and insects from this location as background noise) to increase

[1] The prototype will be available open source. To ensure anonymity, the link will be revealed upon acceptance.

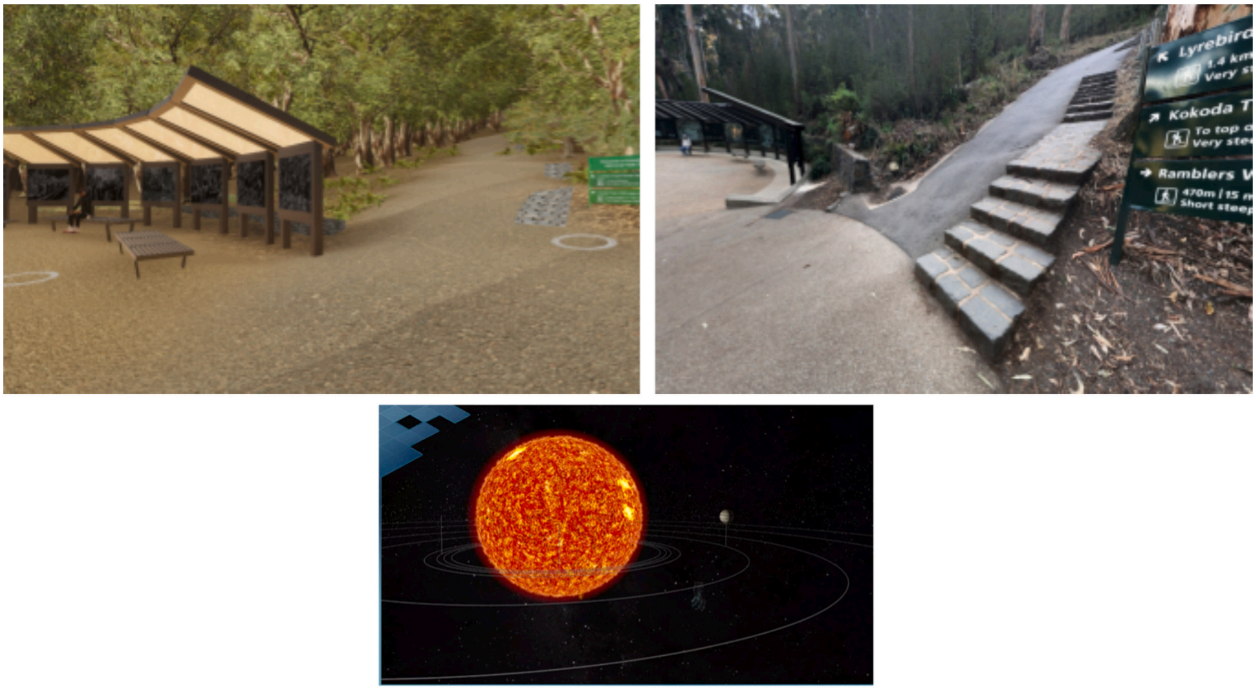

Fig. 1. The two experiences proposed in our study. Top: Scene 1 of the Kokoda Track Memorial Walk experience recreated on Unity (left) using a 360 Google Streetview picture (right). Bottom: The solar system exploration VR application was used as the control condition.

vividness and realism. Participants could move between several teleportation points in each scene. One of these led to the next scene. At each point, participants were able to physically move around to explore the scene.

2.3.2. Control condition

The control simulation had to be of similar nature (i.e., exploration of an environment) and appeal but lack the episodic (personally relevant) and future-oriented attributes of EFT. We used a solar system demonstration from The Lab application created by Valve (Valve, 2021) (see Fig. 1-Bottom). It was chosen as it was likely to provide a positive experience without evoking any personal past or future memories. In this scene, participants, similarly to the active EFT condition, could also move around using teleportation, and physically explore the scene.

2.4. Measures

We collected data on participants' intertemporal choices to estimate their delay discounting (main outcome measure) and several control variables, listed below.

2.4.1. Delay discounting

We applied a purpose-built, titration-based intertemporal choice questionnaire, adapted from (Du et al., 2002). This questionnaire presented options where participants chose between hypothetical monetary rewards available at different times. The titrating-alternatives method is time-effective and produces more systematic and valid data compared to other techniques (Rung et al., 2018). The intertemporal choice task contained six randomised blocks of six choices. The first three blocks contained sooner options hypothetically arriving in the present (i.e., now) and later options where the delay varied between one week, two months and one year (approximately evenly spaced on a logarithmic scale). In the next three blocks, both options were shifted into the future by one year. Each block began with a choice between a larger-later reward ($1000) and a smaller-sooner reward half the value of the delayed reward ($500). For each subsequent choice, the amount of the smaller-sooner option was adjusted based on the participant's previous choice. The intertemporal choice questionnaire allowed us to estimate quasi-hyperbolic discounting model parameters for each participant (Laibson, 1997). The model is formalised as follows:

$$V = A(\beta\delta^{\tau}) \tag{1}$$

In the above, A is the monetary amount associated with an option, β represents present bias, δ is time-sensitive devaluation, and τ is the delay. For more information about the options in the choice set, see Supplementary Material.

2.4.2. Presence

We measured the sense of presence in VR to control for the participant's level of immersion across conditions. For this purpose, we used the Igroup Presence Questionnaire (IPQ) which measures the subjective sense of being in a virtual environment using three subscales: (1) spatial presence, which measured the sense of being physically present in the virtual environment; (2) involvement, which measured attention and participation in the virtual environment; and (3) experienced realism, which measured the subjective experience of realism in the virtual environment (Schubert et al., 2001).

2.4.3. Mood

We measured the participants' mood change after the simulations to control for its impact on their intertemporal choices. To do so, mood was measured before and after the simulation through a self-report visual analogue scale where participants rated their mood by moving a slider, from the midpoint, along a continuum towards the left for terrible (0) or the right for terrific (100).

2.5. Procedure

Participation was voluntary and informed consent was obtained before the study. Participants completed an eligibility questionnaire at least two days before the experiment, which included the SUPPS-P. The eligibility questions related to their age (18 or older), whether they had a history of epilepsy or seizure, whether they could move their arms and legs, whether they could read and do simple arithmetic, and whether

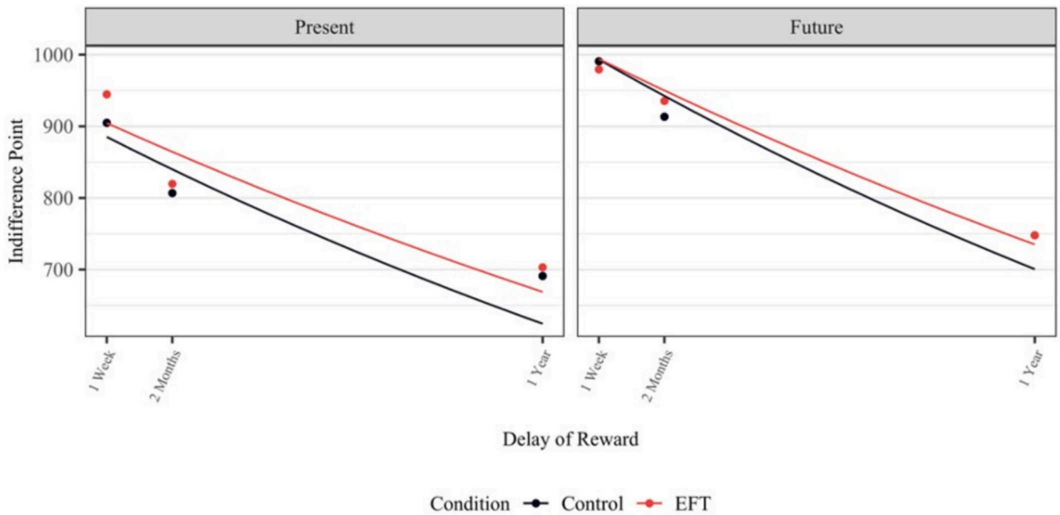

Fig. 2. Indifference points represent participants' hypothetical subjective value of $1000 of the larger-later option with reference to the sooner option (y-axis) following the VR-based EFT (represented in red) and control simulation (represented in purple). The delay between smaller-sooner rewards and larger-later rewards (x-axis) is either 1 week, 2 months, or 1 year. The left panel illustrates choices where the smaller-sooner reward would be received immediately, whereas the right panel shows those same choices with both options shifted one year into the future (e.g., $500 in one year or $1000 in one year and one week). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

they had visited the Kokoda Track (1000 Steps Walk). Participants were also asked via email not to drink caffeine in the six hours before the experiment. All procedures were followed in accordance with the Monash University Human Research Ethics Council ethical approval 26342.

The experiment began with a pre-test questionnaire asking participants to rate their mood on the visual analogue scale and whether they had caffeine in the previous six hours (see Supplementary Materials in our preregistration). Participants were then shown how to wear the headset and use the controllers. Once the participant indicated they were ready to proceed, the experimental or control simulation was introduced. The experimenter read the instructions for the participant's allocated simulation including what they were to expect, the aim of the session—either to experience a future memory (1000 Steps Walk) or have a positive VR experience (solar system)—and how to navigate the virtual world. Participants spent an average of 3.38 min (*SD* = 1.05 min) in the EFT simulation, and were asked to exit the solar system after 3 min.

Following the simulation, participants completed the post-test questionnaire, containing the mood visual analogue scale, intertemporal choice questionnaire, and the IPQ. Following the 1000 Steps simulation only, they also answered verbal and written manipulation check questions. For further details on manipulation checks, see Supplementary Material.

2.6. Data analysis

For our main analysis, we used Bayesian hierarchical models to identify the effect of the condition on discounting parameters β and δ. Numeric predictors age, mood, and SUPPS-P score, were mean-centred.

Similarly, the second hypothesis that individuals would commit fewer preference reversals following VR-based EFT, compared the magnitude of participants' preference reversals across the two conditions through a Bayesian hierarchical model. See Supplementary Material for further information on the details and interpretation of the Bayesian analysis.

2.6.1. Potential moderators

To control for the impact of the participants' mood on delay discounting rates, descriptive statistics of the differences in the mood before and after each condition were examined, and a Bayesian t-test was performed. Lastly, to check whether the level of presence experienced was different during the EFT and control conditions, descriptive statistics of the IPQ subscales were examined and a Bayesian t-test of the total presence scores of each condition was performed.

3. Results

Present bias decreased following the VR-based EFT condition, compared to the control, by $20 (EFT: β M = 0.91, SD = 0.13, Control: β M = 0.89, SD = 0.20). Time-sensitive devaluation of rewards decreased following the VR-based EFT condition, compared to the control, by $40 per year (EFT: δ M = 0.74, SD = 0.18, Control: δ M = 0.70, SD = 0.27). The Bayes Factor, however, indicated anecdotal evidence towards the null hypothesis, suggesting an absence of effect of VR-based EFT on the participant's present bias (BF = 0.16) and time-sensitive devaluation (BF = 0.27). The error percentage for present bias and delay discounting calculated through the Markov Chain Monte Carlo indicated numeric robustness and successful model convergence (MCSE = 0.0, Rhat = 1.0).

The effect of VR-based EFT on β had a 73.74% probability of being positive (median = 0.02, 95% CI [−0.04, 0.08]). An increase in β indicates lowered present bias. The effect of VR-based EFT on δ had an 82.80% probability of being positive (median = 0.03, 95% CI [−0.04, 0.11]). An increase in δ indicates lowered time-sensitive devaluation of the delayed reward.

A visual illustration of the positive effects of VR-based EFT on present bias and time-sensitive devaluation can be seen in Fig. 2, where participants report higher indifference points in the EFT condition compared to the control condition, in both the present- and future-based intertemporal choice questions. The steep drop in the intercept of the indifference points in the present panel of Fig. 2 compared to the future panel, illustrates present bias. The slope of the indifference points represents time-sensitive devaluation which is less steep following the VR-based EFT condition.

The magnitude of preference reversals decreased by $17.52 following the VR-based EFT condition compared to the control (EFT M = 65.34, SD = 182.52, Control M = 82.86, SD = 228.72). The effect of EFT on preference reversals had a probability of 72.42% of being negative (Median = −16.37, 95% CI [−69.65, 38.50]). The Bayes Factor indicated moderate evidence towards the null hypothesis, suggesting an absence of effect of EFT on the magnitude of preference reversals (BF = 0.31). The error percentage calculated through MCMC indicated acceptable numeric robustness and model convergence (mcse = 0.2, Rhat = 1.0).

There was a slight variation in presence experienced in the VR EFT (M = 13.66, SD = 2.63) and control (M = 13.14, SD = 2.42) simulations. Variability in the IPQ subscales was observed, with higher spatial presence and experienced realism reported following the EFT condition and higher involvement experienced following the control condition. However, anecdotal evidence suggests there were no major differences between conditions (BF = 0.36).

Differences in mood (i.e., mood after simulations subtracted from mood prior to simulations), were positive after both the EFT (M = 0.86, SD = 0.99) and control (M = 1.14, SD = 1.28) simulations. There was anecdotal evidence of no major differences in mood between conditions (BF = 0.38).

4. Discussion and conclusion

The current study examined the feasibility and preliminary efficacy of VR as a tool for facilitating EFT in healthy participants as prima facie evidence for subsequent studies in clinical populations such as behavioural addictions. EFT has been shown to reduce delay discounting in various health promotion contexts (Stein et al., 2017). However, for EFT to be effective, individuals must be able to produce positive, detailed, and vivid future thoughts of the future from a first-person perspective (Wang et al., 2019), which is particularly challenging for people with affective dysregulation and heightened sensitivity to cues signalling immediate (rather than future) reward, such as people with behavioural addictions (Berridge & Robinson, 2016). We found no statistical evidence that EFT in VR had an attenuating effect on present bias and time-sensitive devaluation of outcomes. Quantitatively, the effect size was non-trivial, but the sample size was too small to give any degree of precision in the credible interval. However, the differences between conditions suggest that EFT may have occurred in VR.

Investigating changes in discounting through present bias and time-sensitive devaluation as two separate parameters is a novel approach to measure EFT effects which offers interesting insights for behavioural addictions, which are characterised by steep discounting rates. The existing literature regarding the impact of EFT on time preferences predominantly relies on the hyperbolic discounting model, which accounts for present bias and time-sensitive devaluation of outcomes through one discounting parameter (Mazur, 1987). Our use of the quasi-hyperbolic discounting model allowed us to investigate whether EFT impacts the tendency to overvalue present rewards specifically, or whether there are persistent changes to the subjective value of rewards over time. The current study identified initial signs of possible changes in both present bias and time-sensitive devaluation following EFT, which suggests EFT may simultaneously reduce salience attribution/cue-reactivity (present bias) and increase value representations of future rewards. If confirmed, these therapeutic mechanisms could contribute to reducing, for example, gambling-related cravings and increase the appeal of alternative future rewards in people with behavioural addictions (Wiehler et al., 2017).

The Bayes Factors did not support our hypotheses, largely due to the relative future-orientedness of our sample. Although the estimates are uncertain, we observed a reduction in preference reversals following the VR-based EFT simulation compared to the control VR simulation in our sample. That measurement is important because understanding an individual's tendency to reverse their preferences provides insight into their actual behaviour if a reward was offered immediately (Doyle, 2012), which has implications for behavioural addictions (Albein-Urios et al., 2014; Amlung et al., 2017), as well as other related aspects such as personal finance (Laibson, 1997), and public health (van Baal et al., 2023). Preference reversals are closely related to present bias, as an individual who is biased towards accepting immediate rewards will be more likely to momentarily prefer available rewards over their goals for the future. The effects of EFT on preference reversals are largely unaddressed in the literature and are thus important when considering the existing findings on the impact of EFT on decision-making.

The Bayes Factor results did not favour our hypotheses, and the models indicate uncertain estimates of EFT occurring during a VR simulation. We do find it noteworthy that all the dependent variables moved in the right direction quantitatively. We believe this constitutes grounds for further investigation of VR-based EFT protocols. This study aims to provide a basis for investigating the occurrence of EFT in VR and measuring the impact of EFT through the quasi-hyperbolic discounting model.

An additional aim of conducting the current proof-of-concept study was to identify the feasibility of the procedure and any potential variables that may impact the results of the study. The utility of VR is constrained by the level of presence the user experiences within a simulation (Habak et al., 2021). In the current study, no differences in presence were identified between conditions. This finding supports the robustness of our study design, suggesting the level of presence experienced is not a confound for the differences in discounting rates following the simulations.

Another variable that could have influenced participants' intertemporal choices was their affective state. Sadness has been found to exacerbate present-biased monetary decision-making (Lerner et al., 2013) and higher levels of positive affect (Pyone & Isen, 2011) and related thought processes, such as gratitude (DeSteno et al., 2014), increase future-oriented decision-making. The current study found no differences in mood between conditions, indicating there was no evidence that mood was differentially impacted by the simulations. Following both simulations mood improved slightly, indicating that the experimental and control procedure and simulations were not unpleasant or negatively experienced by the participants. This supports the utilisation of the present study's procedure and simulations in a larger study.

Participants unexpectedly did not report any motion sickness for both the control simulation and the 1000 Steps simulation. They verbally reported they found the 1000 Steps Walk a tranquil experience, and enjoyed being immersed in the virtual environment. These experiences highlight that user acceptance of related treatments could be high. The 1000 Steps Walk scene was developed to create a familiar environment with positive connotations for a large number of people in the geographical area. Creating such a scene requires some technical skill, but perhaps a set of more general experiences can be developed, which can be applied more widely.

4.1. Limitations and future directions

The uncertainty of the estimates of the effect of VR-based EFT on present bias, time-sensitive devaluation, and preference reversals is indicative of the small sample size and ceiling effects. Participants' baseline discount rate, identified in the control condition, was already low, as indicated by high average β and δ, representing low present bias and time-sensitive devaluation. In addition, the below mid-point scores on the impulsivity scale (SUPPS-P) indicate a generally low-trait impulsivity sample.

Another limitation of our experiment is that it did not address whether VR-based EFT improved traditional EFT methods of enhancing future thinking. As a proof-of-concept study, our aim was to identify whether utilising VR allowed individuals to overcome barriers of EFT engagement, such as the reliance on memory and emotion processes, that impact the ability to produce detailed future thoughts. A comparison of two active interventions was therefore out of the scope of this paper. Further, it is possible that our control condition, immersing oneself in space, differentially impacts intertemporal choice.

Future research should investigate whether VR can enable EFT in a larger sample. A larger sample would help to increase the certainty of

Fig. 3. The 3 scenes of the 1000 step walk experience recreated on Unity (left) using a 360 Google StreetView picture (right).

whether EFT occurs during a VR simulation and its impact on time preferences. In particular, we believe that EFT in VR could be tested with samples of people who have trouble imagining the future, subclinical samples, or with people who are more present-oriented.

CRediT authorship contribution statement

Simon T. van Baal: Writing – review & editing, Writing – original draft, Visualization, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Verity Petratos:** Writing – original draft, Project administration, Investigation, Data curation. **Arnaud Prouzeau:** Writing – review & editing, Visualization, Software, Methodology, Investigation, Conceptualization. **Adélaïde Genay:** Writing – review & editing, Software, Methodology, Conceptualization. **Antonio Verdejo-García:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Funding

This study was funded by an Australian National Health and Medical Research Council (NHMRC) grant: 2009464.

Declaration of competing interest

All authors declare no conflict of interest.

Acknowledgements

We wish to thank Jakob Hohwy for his contributions to the conceptualisation of this project.

Appendix A. Research methods

A.1. Virtual reality

The 1000 Steps Walk was chosen for the VR-based EFT environment because it is a popular walk in the Melbourne region, commonly associated with positive factors such as exercise, socialising and travel. This positivity can contribute to the effects of episodic future thinking (Barsics et al., 2016). The popularity of the walk increased the inclusivity of the sample.

See Fig. 3 for screenshots of the three created scenes and the 360 pictures from Google StreetView it was inspired from.

To further contribute to the positivity of the experience, animated individuals appearing throughout the walk exchanged positive dialogue about the pleasant weather and how it feels good to be physically active. The simulation mimicked real-life experiences where the animated characters in the environment were walking and looking around, and the individual experiencing the simulation could hear the sounds from their movements and conversations fade in and out depending on their proximity to the animated characters. Before entering the simulation, participants were reminded to use their previous experiences at the 1000 Steps to help stimulate EFT in the simulation. Each participant followed the same path through the simulation as they were instructed to use the teleportation points to move throughout and between scenes. Teleportation points are circles appearing throughout a simulation that allow the individual to navigate large virtual environments without moving extensively in the physical space.

Participants used the controller to point to a target position and were taken there with minimal physical movement (Bozgeyikli et al., 2016).

A.2. Measures

A.2.1. Intertemporal choice task

For the intertemporal choice task, participants were instructed that they should choose which option they preferred, with a smaller monetary reward they would receive sooner (smaller-sooner) on the left-hand side, and a larger amount they would receive later (larger-later) on the right-hand side.

If the smaller-sooner option was selected, the amount of the next smaller-sooner option decreased and if the larger-later option was selected, the next smaller-sooner reward increased. The adjustment between successive choices varied: the first adjustment was $250, and for subsequent choices the adjustment was half of the previous adjustment.

For the purpose of the analysis, the indifference point was assumed to be equal to the smaller-sooner choice that would have been proposed in the next (seventh) choice, had it been presented. This approximates the value at which the participant would be indifferent between the two rewards.

A.2.2. Igroup Presence Questionnaire

Each subscale ranges from zero to six, with the total questionnaire ranging from zero to eighteen. Higher scores indicate greater presence experienced during the simulation. Each subscale has an acceptable internal consistency of $\alpha = 0.62$, $\beta = 0.60$, and $\beta = 0.60$ for spatial presence, involvement, and realism, respectively and a good total questionnaire internal consistency of 0.85–0.87 (Iachini et al., 2019). Slightly higher internal consistencies of 0.84 for spatial presence, 0.68 for involvement, 0.69 for realism have also been found (Schaik & Drummond, 2004). Similar factor structures to other presence questionnaires and the ability to distinguish multiple aspects of presence demonstrate the IPQs construct and predictive validity (Grassini et al., 2020; Schubert et al., 2001).

A.2.3. SUPPS-P

The SUPPS-P has been shown to have an acceptable to good internal reliability of 0.70–0.81 and replicates inter-correlations, variance and internal validity of the full UPPS-P (Cyders et al., 2014).

A.2.4. Manipulation checks

Factual treatment-relevant manipulation checks identified participants who paid attention and understood the experimental condition as it was intended (Kane & Barabas, 2019). Following the VR-based EFT simulation, participants described their future experience to the experimenter and answered "when were you in the simulation (in time)?" and "where were you in the simulation?" in the post-simulation questionnaire. Participants who did not provide a future-orientated description of their future memory and did not identify the simulation was in a future timepoint at the 1000 Steps would be excluded.

A.3. Analysis

We used the rstanarm package for Bayesian modelling (Carpenter et al., 2017), emmeans package for calculating marginal means (Lenth et al., 2018) and additional packages outlined in Appendix A. Highest Density Intervals (HDI) and Bayes Factors were calculated through pairwise comparison of the estimated marginal means using the Savage-Dickey ratio method.

To test the first hypothesis, that VR-based EFT decreases present bias and time-sensitive devaluation, we used nonlinear Maximum Likelihood techniques to estimate the present bias (β) and time-sensitive devaluation (δ) parameters of the quasi-hyperbolic discounting model (Laibson, 1997). To identify the effect of VR-based EFT on β and δ, we analysed the data using a Bayesian hierarchical model and included the condition and session as predictors, participant as the random intercept, and the model used weakly informed priors. The prior probability distribution was weakly informed through pre-existing knowledge of β and δ as being bound between zero and one, and through simulated prior predictions. A normally distributed intercept prior with a mean of 0.5 and standard deviation of 0.15, a normally distributed prior with a mean of 0 and standard deviation of 0.15 was used for the predictors and the random intercept. The model was run with four Markov Chain Monte Carlo chains with 1000 warm-ups and 25,000 iterations per chain.

The magnitude of the effect of the condition on preference reversals was estimated by comparing indifference points between present-based blocks, where participants were asked to choose between an immediate reward and a delayed reward (blocks 1, 2, and 3), and future-based blocks where both options were shifted one year into the future (blocks 4, 5, and 6). To evaluate the effect of the manipulation on preference reversals, we used a Bayesian hierarchical model with predictors: condition, block, an interaction term of condition and block, and session. The participant was included as the random intercept. The prior probability distribution was weakly informed through prior knowledge of the frequency of preference reversals and simulated prior predictions. A normally distributed intercept prior with a mean of 150 and standard deviation of 100 was used for the predictors, a normally distributed prior with a mean of 0 and a standard deviation of 75 was used the random intercept. The model was run with four Markov Chain Monte Carlo (MCMC) chains with 1000 warmups, 10000 iterations per chain.

A.3.1. Interpretation of Bayesian analysis

The posterior distribution of the estimates reflects the 'updated knowledge' as it considers the data that has been collected in combination with the pre-existing information (Schoot & Depaoli, 2014).

The 95% Highest Density Interval (HDI) is a method of summarising the posterior distributions, it contains the 95% most credible values (Kruschke & Liddell, 2018).

Bayes factors are utilised to express ratios of likelihood towards the alternative or null hypothesis (see e.g., Beard et al., 2016). Importantly, Bayes factors differentiate between weak evidence for an effect and lack of evidence for an effect. For our study, we used inference criteria where 1–3 was considered anecdotal evidence, 3–10 moderate, 10–30 strong, 30–100 very strong and $>$ 100 extreme evidence (Jeffreys, 1998).

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.actpsy.2026.106912.

Data availability

The data is available via a link in the manuscript.

References

Ainslie, G. (1975). Specious reward: A behavioral theory of impulsiveness and impulse control. *Psychological Bulletin, 82*(4), 463.

Albein-Urios, N., Martinez-González, J. M., Lozano, Ó., & Verdejo-Garcia, A. (2014). Monetary delay discounting in gambling and cocaine dependence with personality comorbidities. *Addictive Behaviors, 39*(11), 1658–1662. https://doi.org/10.1016/j.addbeh.2014.06.001

Amlung, M., Marsden, E., Holshausen, K., Morris, V., Patel, H., Vedelago, L., … McCabe, R. E. (2019). Delay discounting as a transdiagnostic process in psychiatric disorders: A meta-analysis. *JAMA Psychiatry, 76*(11), 1176–1186. https://doi.org/10.1001/jamapsychiatry.2019.2102

Amlung, M., Vedelago, L., Acker, J., Balodis, I., & MacKillop, J. (2017). Steep delay discounting and addictive behavior: A meta-analysis of continuous associations. *Addiction, 112*(1), 51–62. https://doi.org/10.1111/add.13535

Barsics, C., Van der Linden, M., & D'Argembeau, A. (2016). Frequency, characteristics, and perceived functions of emotional future thinking in daily life. *Quarterly Journal of Experimental Psychology, 69*(2), 217–233. https://doi.org/10.1080/17470218.2015.1051560

Beard, E., Dienes, Z., Muirhead, C., & West, R. (2016). Using Bayes factors for testing hypotheses about intervention effectiveness in addictions research. *Addiction, 111*(12), 2230–2247. https://doi.org/10.1111/add.13501

Berridge, K. C., & Robinson, T. E. (2016). Liking, wanting and the incentive-sensitization theory of addiction. *The American Psychologist, 71*(8), 670–679. https://doi.org/10.1037/amp0000059

Bickel, W. K., & Marsch, L. A. (2001). Toward a behavioral economic understanding of drug dependence: Delay discounting processes. *Addiction, 96*(1), 73–86.

Bozgeyikli, E., Raij, A., Katkoori, S., & Dubey, R. (2016). Point & teleport locomotion technique for virtual reality. In *Proceedings of the 2016 annual symposium on computer-human interaction in Play, CHI PLAY '16* (pp. 205–216). https://doi.org/10.1145/2967934.2968105

Brown, J. M., & Stein, J. S. (2022). Putting prospection into practice: Methodological considerations in the use of episodic future thinking to reduce delay discounting and maladaptive health behaviors. *Frontiers in Public Health, 10*, Article 1020171. https://doi.org/10.3389/fpubh.2022.1020171

Brown, T., Vogel, E. N., Adler, S., Bohon, C., Bullock, K., Nameth, K., … Runfola, C. D. (2020). Bringing virtual reality from clinical trials to clinical practice for the treatment of eating disorders: An example using virtual reality cue exposure therapy. *Journal of Medical Internet Research, 22*(4), Article e16386. https://doi.org/10.2196/16386

Bulley, A., & Gullo, M. J. (2017). The influence of episodic foresight on delay discounting and demand for alcohol. *Addictive Behaviors, 66*, 1–6. https://doi.org/10.1016/j.addbeh.2016.11.003

Carpenter, B., Gelman, A., Hoffman, M. D., Lee, D., Goodrich, B., Betancourt, M., … Riddell, A. (2017). Stan: A probabilistic programming language. *Journal of Statistical Software, 76*(1). https://doi.org/10.18637/jss.v076.i01

Cyders, M. A., Littlefield, A. K., Coffey, S., & Karyadi, K. A. (2014). Examination of a short English version of the UPPS-P Impulsive Behavior Scale. *Addictive Behaviors, 39*(9), 1372–1376. https://doi.org/10.1016/j.addbeh.2014.02.013

DeSteno, D., Li, Y., Dickens, L., & Lerner, J. S. (2014). Gratitude: A tool for reducing economic impatience. *Psychological Science, 25*(6), 1262–1267. https://doi.org/10.1177/0956797614529979

Doyle, J. R. (2012). Survey of time preference, delay discounting models. In *Delay discounting models* (April 20, 2012).

Du, W., Green, L., & Myerson, J. (2002). Cross-cultural comparisons of discounting delayed and probabilistic rewards. *The Psychological Record, 52*(4), 479–492.

Friedman, D., Pizarro, R., Or-Berkers, K., Neyret, S., Pan, X., & Slater, M. (2014). A method for generating an illusion of backwards time travel using immersive virtual reality—An exploratory study. *Frontiers in Psychology, 5*. https://doi.org/10.3389/fpsyg.2014.00943

Göllner, L. M., Ballhausen, N., Kliegel, M., & Forstmeier, S. (2018). Delay of gratification, delay discounting and their associations with age, episodic future thinking, and future time perspective. *Frontiers in Psychology, 8*. https://doi.org/10.3389/fpsyg.2017.02304

Grassini, S., Laumann, K., & Rasmussen Skogstad, M. (2020). The use of virtual reality alone does not promote training performance (but sense of presence does). *Frontiers in Psychology, 11*. https://doi.org/10.3389/fpsyg.2020.01743

Habak, S., Bennett, J., Davies, A., Davies, M., Christensen, H., & Boydell, K. M. (2021). Edge of the present: A virtual reality tool to cultivate future thinking, positive mood and wellbeing. *International Journal of Environmental Research and Public Health, 18*(1), Article 1. https://doi.org/10.3390/ijerph18010140

Hallford, D. J., Austin, D. W., Takano, K., & Raes, F. (2018). Psychopathology and episodic future thinking: A systematic review and meta-analysis of specificity and episodic detail. *Behaviour Research and Therapy, 102*, 42–51. https://doi.org/10.1016/j.brat.2018.01.003

Iachini, T., Maffei, L., Masullo, M., Senese, V. P., Rapuano, M., Pascale, A., … Ruggiero, G. (2019). The experience of virtual reality: Are individual differences in mental imagery associated with sense of presence? *Cognitive Processing, 20*(3), 291–298. https://doi.org/10.1007/s10339-018-0897-y

Ioannidis, K., Hook, R., Wickham, K., Grant, J. E., & Chamberlain, S. R. (2019). Impulsivity in gambling disorder and problem gambling: A meta-analysis. *Neuropsychopharmacology, 44*(8), 1354–1361. https://doi.org/10.1038/s41386-019-0393-9

Jeffreys, H. (1998). *The theory of probability*. OUP Oxford.

Kalhan, S., Garrido, M. I., Hester, R., & Redish, A. D. (2023). Reward prediction-errors weighted by cue salience produces addictive behaviours in simulations, with asymmetrical learning and steeper delay discounting. *Neural Networks: The Official Journal of the International Neural Network Society, 168*, 631–650. https://doi.org/10.1016/j.neunet.2023.09.032

Kane, J. V., & Barabas, J. (2019). No harm in checking: Using factual manipulation checks to assess attentiveness in experiments. *American Journal of Political Science, 63*(1), 234–249. https://doi.org/10.1111/ajps.12396

Kayser, A. (2019). Dopamine and gambling disorder: Prospects for personalized treatment. *Current Addiction Reports, 6*(2), 65–74. https://doi.org/10.1007/s40429-019-00240-8

Kruschke, J. K., & Liddell, T. M. (2018). The Bayesian New Statistics: Hypothesis testing, estimation, meta-analysis, and power analysis from a Bayesian perspective. *Psychonomic Bulletin & Review, 25*(1), 178–206. https://doi.org/10.3758/s13423-016-1221-4

Laibson, D. (1997). Golden eggs and hyperbolic discounting. *The Quarterly Journal of Economics, 112*(2), 443–478. https://doi.org/10.1162/003355397555253

Lawrence, A. J., Luty, J., Bogdan, N. A., Sahakian, B. J., & Clark, L. (2009). Problem gamblers share deficits in impulsive decision-making with alcohol-dependent individuals. *Addiction, 104*(6), 1006–1015.

Lenth, R., Singmann, H., Love, J., Buerkner, P., & Herve, M. (2018). Emmeans: Estimated marginal means, aka least-squares means. *R Package Version, 1*(1), 3.

Lerner, J. S., Li, Y., & Weber, E. U. (2013). The financial costs of sadness. *Psychological Science, 24*(1), 72–79. https://doi.org/10.1177/0956797612450302

Loewenstein, G., & Thaler, R. H. (1989). Anomalies: Intertemporal choice. *Journal of Economic Perspectives, 3*(4), 181–193. https://doi.org/10.1257/jep.3.4.181

Mazur, J. E. (1987). An adjusting procedure for studying delayed reinforcement. *Quantitative Analyses of Behavior, 5*, 55–73.

O'Neill, J., Daniel, T. O., & Epstein, L. H. (2016). Episodic future thinking reduces eating in a food court. *Eating Behaviors, 20*, 9–13. https://doi.org/10.1016/j.eatbeh.2015.10.002

Potenza, M. N., Balodis, I. M., Derevensky, J., Grant, J. E., Petry, N. M., Verdejo-Garcia, A., & Yip, S. W. (2019). Gambling disorder. *Nature Reviews Disease Primers, 5*(1), Article 51. https://doi.org/10.1038/s41572-019-0099-7

Pyone, J. S., & Isen, A. M. (2011). Positive affect, intertemporal choice, and levels of thinking: Increasing consumers' willingness to wait. *Journal of Marketing Research, 48*(3), 532–543. https://doi.org/10.1509/jmkr.48.3.532

Race, E., Keane, M. M., & Verfaellie, M. (2011). Medial temporal lobe damage causes deficits in episodic memory and episodic future thinking not attributable to deficits in narrative construction. *Journal of Neuroscience, 31*(28), 10262–10269. https://doi.org/10.1523/JNEUROSCI.1145-11.2011

Rung, J. M., Argyle, T. M., Siri, J. L., & Madden, G. J. (2018). Choosing the right delay-discounting task: Completion times and rates of nonsystematic data. *Behavioural Processes, 151*, 119–125. https://doi.org/10.1016/j.beproc.2018.03.022

Rung, J. M., & Madden, G. J. (2018). Experimental reductions of delay discounting and impulsive choice: A systematic review and meta-analysis. *Journal of Experimental Psychology. General, 147*(9), 1349–1381. https://doi.org/10.1037/xge0000462

Schacter, D. L., Benoit, R. G., & Szpunar, K. K. (2017). Episodic future thinking: Mechanisms and functions. *Current Opinion in Behavioral Sciences, 17*, 41–50. https://doi.org/10.1016/j.cobeha.2017.06.002. Memory in Time and Space.

Schaik, P. V., & Drummond, S. (2004). Presence within a mixed reality environment. *Cyberpsychology & Behavior, 7*(5).

Schoot, R.v.d., & Depaoli, S. (2014). Bayesian analyses: Where to start and what to report. *European Health Psychologist, 16*(2), 75–84.

Schubert, T., Friedmann, F., & Regenbrecht, H. (2001). The experience of presence: Factor analytic insights. *Presence Teleoperators and Virtual Environments, 10*(3), 266–281. https://doi.org/10.1162/105474601300343603

Segovia, M. S., Palma, M. A., & Nayga, R. M., Jr. (2020). Can episodic future thinking affect food choices? *Journal of Economic Behavior & Organization, 177*, 371–389. https://doi.org/10.1016/j.jebo.2020.06.019

Stein, J. S., Sze, Y. Y., Athamneh, L., Koffarnus, M. N., Epstein, L. H., & Bickel, W. K. (2017). Think fast: Rapid assessment of the effects of episodic future thinking on delay discounting in overweight/obese participants. *Journal of Behavioral Medicine, 40*(5), 832–838. https://doi.org/10.1007/s10865-017-9857-8

Stein, J. S., Tegge, A. N., Turner, J. K., & Bickel, W. K. (2018). Episodic future thinking reduces delay discounting and cigarette demand: An investigation of the good-subject effect. *Journal of Behavioral Medicine, 41*(2), 269–276. https://doi.org/10.1007/s10865-017-9908-1

Sun, H.-Y., Jiang, Y.-P., Wang, X., Cui, L.-Y., & Sun, H.-M. (2023). The effect of episodic foresight on intertemporal decision-making: The role of future self-continuity and perceived control. *Cognitive Processing, 24*(2), 173–186. https://doi.org/10.1007/s10339-023-01124-6

Szpunar, K. K. (2010). Episodic future thought: An emerging concept. *Perspectives on Psychological Science, 5*(2), 142–162. https://doi.org/10.1177/1745691610362350

Valve. (2021). *SteamVR*. Valve (Computer software).

van Baal, S. T., Verdejo-García, A., & Hohwy, J. (2023). Episodic future thinking and compassion reduce non-compliance urges regarding public health guidelines: A randomised controlled trial. *BMC Public Health, 23*(1), 189. https://doi.org/10.1186/s12889-023-15031-0 van Baal, S. T., Walasek, L., Verdejo-García, A., & Hohwy, J. (2025). Impulsivity and self-control as timeless concepts: A conceptual analysis of intertemporal choice. *Decision, 12*(2), 165–189. https://doi.org/10.1037/dec0000257

Verdejo-García, A., Alcázar-Córcoles, M. A., & Albein-Urios, N. (2019). Neuropsychological interventions for decision-making in addiction: A systematic review. *Neuropsychology Review, 29*(1), 79–92. https://doi.org/10.1007/s11065-018-9384-6

Wang, T., Mellis, A. M., Lau, N., & Bickel, W. (2019). Integrating episodic future thinking into virtual reality to mitigate substance use disorders: A theoretical framework. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 63*(1), 2282–2286. https://doi.org/10.1177/1071181319631026

Wiehler, A., Petzschner, F. H., Stephan, K. E., & Peters, J. (2017). Episodic tags enhance striatal valuation signals during temporal discounting in pathological gamblers. *eNeuro, 4*(3), Article ENEURO.0159-17.2017. https://doi.org/10.1523/ENEURO.0159-17.2017

Glossary

BF: Bayes Factor
EFT: Episodic future thinking
IPQ: Igroup Presence Questionnaire
SUPPS-P: Short Urgency, Premeditation, Perseverance, Sensation seeking, and Positive urgency scale
VR: Virtual reality