

Real-World Methods of Autobiographical Recall in Virtual Reality

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Figure 1: We investigated four methods of autobiographical recall in virtual reality, where participants elaborated on past events in different ways. (Left) Avatar Methods: Two methods involved talking to a virtual avatar. In one method, participants spoke to a computer-controlled avatar, and in the other, the virtual avatar was a proxy for the researcher. (Middle) Thinking Quietly: Participants thought about a past event without expressing it. (Right) VR Pen: Participants drew or wrote about a past event using a VR pen.

ABSTRACT

Autobiographical Recall (ABR) is a method for eliciting emotions by recalling past personal events (e.g., recalling a happy memory to induce happiness). ABR could have many uses in virtual reality (VR), ranging from virtual therapy to training and research. However, we currently do not know how users experience ABR in VR and how effective they are relative to each other. Hence, we investigate how well real-world ABR methods work in VR. We conducted a user study ($N=17$) where participants evoked emotions using four ABR methods: thinking quietly, writing/drawing, talking to a virtual avatar, and talking to an avatar connected to another person. Our results show that 1) all methods of ABR were equally successful in inducing changes in emotion, and 2) the users' experiences with the different methods varied, yet, methods in which events are recalled in private were generally deemed most comfortable (writing/drawing, thinking quietly).

*This work was done while with LMU Munich.

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NordiCHI '22, October 8–12, 2022, Aarhus, Denmark

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<https://doi.org/10.1145/3546155.3546704>

CCS CONCEPTS

- Human-centered computing → Virtual reality; Empirical studies in HCI

KEYWORDS

autobiographical recall, virtual reality, virtual avatars, research methods

ACM Reference Format:

Laura Götz, Radiyah Rivu, Florian Alt, Albrecht Schmidt, and Ville Mäkelä. 2022. Real-World Methods of Autobiographical Recall in Virtual Reality. In *Nordic Human-Computer Interaction Conference (NordiCHI '22)*, October 8–12, 2022, Aarhus, Denmark. ACM, New York, NY, USA, 11 pages. <https://doi.org/10.1145/3546155.3546704>

1 INTRODUCTION

Emotions and their influence on human behavior have been studied actively [15, 29, 34, 36]. Critical to such studies is the elicitation of specific emotions in study participants. There are many techniques for eliciting emotions in humans that include, for example, showing video clips and pictures or playing music [18, 21, 49].

Increasingly, virtual reality (VR) is being used for studies and other activities where emotions and emotion elicitation play a key role. This includes emotion research [13, 40] and also virtual therapy [37, 39] and training [56]. VR is a cost-effective method for creating specific situations and environments, and for controlling and changing them with ease [33, 41]. Furthermore, in VR we can

simulate situations that would be difficult to create or replicate in the real world [33], and situations that would be dangerous or otherwise unethical in the physical world (e.g., certain cases of exposure therapy [37], studies investigating pedestrian crossing behavior [23], the impact of affect on driving [8]).

A particularly prominent method to elicit emotion is *Autobiographical Recall (ABR)*. In this method, participants recall and reflect on *past events in their life* that evoked a certain emotion. ABR can be implemented in many ways. For example, people can write about the events [3, 31, 35] or think about them aloud [50]. The fact that ABR can be implemented in different ways is a highly useful trait, as ABR could then be adjusted to a wide range of virtual scenarios. For example, therapists could change to a different form of ABR to accommodate a patient's particular needs. Similarly, many studies require the participants' visual attention for other tasks (e.g., simulated driving [8]), and ABR could be adjusted to accommodate these situations. Compared to other elicitation methods, ABR offers further advantages, as it does not require any additional materials and it is personal in nature [9]. Furthermore, ABR has been shown to outperform other induction techniques [9, 26].

However, we currently lack knowledge about how effective the different implementations of ABR are in eliciting emotions in virtual reality, and especially how users experience these different approaches to ABR. For example, it is unclear how users might feel about recalling personal events by themselves in VR, or how they might feel about talking to a virtual agent. Investigating the different approaches will help researchers understand which approach would work best in a particular research context. Prior research has investigated and shown the effectiveness of isolated implementations of ABR in VR in comparison to real-world implementations [40], but has not conducted comparative studies on different ABR methods, nor has prior research looked into the user experience of these methods, and how comfortable they are to users. There are also some approaches to ABR, like writing, that have not been evaluated in virtual reality before. We focus on investigating ABR methods that are familiar from the real world, because there are many virtual situations (e.g., training, certain forms of therapy) where the intention is to mimic the real world as closely as possible.

To address these research gaps, we conducted an exploratory study ($N=17$) to gain insights into how real-world methods of ABR function in VR, how these methods compare relatively to each other, and how they are perceived and experienced by users. Our main research questions are:

RQ1 How effectively do different methods of autobiographical recall elicit emotions in VR?

RQ2 What is the perceived user experience of different methods of autobiographical recall in VR?

To answer these questions, we conducted a within-subjects study where we implemented four different methods of ABR in VR: (1) talking to an artificial avatar, (2) talking to an avatar that served as a proxy for the researcher, (3) thinking quietly, and (4) writing and/or drawing with a VR pen. Each method was combined with one of four target emotions (happiness, sadness, anger, and fear). Participants were asked to recall memories from their life that corresponded to one of the four target emotions, using a different ABR method for each memory.

Our work provided two primary findings. First, all methods of ABR were equally successful in inducing changes in emotion. Second, the perceived user experience regarding the distinct methods varied between participants, however, the methods in which the elaboration takes place in private (writing/drawing, thinking quietly) were generally preferred, as they were seen as more comfortable than the methods involving talking to an avatar or another person. Our results suggest that all four methods have their uses in VR, but that their individual trade-offs, and in some cases, the user's preferences, should be taken into account. For example, a virtual therapy patient who is not comfortable talking to another person in VR when recalling past events could instead opt for writing or thinking quietly about those events.

Contribution statement. Our contribution is twofold. First, we present the design and implementation of four virtual methods of autobiographical recall. Some of the methods have been individually assessed in VR before, but some (like writing/drawing) have not been adapted to VR before our work. Second, we report on the results of a 17-participant user study, where we assessed the effectiveness and user experience of these methods. To our knowledge, we are the first to assess these methods not just by effectiveness, but also by user experience and level of comfort.

2 RELATED WORK

In this section, we first review emotion research that provides the theoretical basis for our work. Then, we review existing emotion elicitation techniques, including the different ways of implementing autobiographical recall. Finally, we discuss the application of emotion elicitation techniques in VR, and show the research gap.

2.1 Basic Emotions and Their Dimensions

Many theories and concepts about emotions have been proposed. Nevertheless, or precisely because of this, researchers and theorists have not come to a clear consensus on a definition for emotion [24]. Izard [24] collected input from more than 30 scientists, summarizing the congruities as follows: "Emotion consists of neural circuits (that are at least partially dedicated), response systems, and a feeling state/process that motivates and organizes cognition and action".

Key to understanding and distinguishing emotions is the concept of *basic emotions*. Theorists agree that these emotions are "in-nate, universal, and distinct affective states which evolved to serve adaptive functions" [27]. Paul Ekman studied emotions and their reflection in facial expressions and cultures [16]. He suggested six basic emotions [16], often referred to as the *Big Six*. They includes happiness, sadness, anger, disgust, fear, and surprise.

Often, emotions are measured along the dimensions of *valence*, *arousal*, and *dominance* (VAD) [42, 43]. Valence refers to the positivity or negativity of an emotional state, arousal to the level of engagement, and dominance to the level of control perceived by the subject over the emotional state or situation [42].

Our work in this paper is based on the theoretical work presented above. We focus on four emotions from the list of basic emotions [16], as they represent the most critical set of emotions. Furthermore, we evaluate the effectiveness of ABR methods using the dimensions of valence, arousal, and dominance (VAD) [42].

2.2 Emotion Elicitation

Researchers also investigated ways in which emotions can be induced in humans. Many so-called *emotion elicitation methods* have been developed. These range from presenting pictures or film clips with emotional content [21, 28, 49], over playing musical pieces [52], to having participants repeat phrases out loud (Velten-like Induction Technique) [51]. Real-life manipulations expose participants to emotion evoking situations without their awareness [22].

The elicitation method at the focus of this study is *Autobiographical Recall* (ABR), also known as autobiographical recollection or autobiographical memory task. In this method, the subject is asked to recall past events from their life that evoked the target emotion, and to elaborate on them with the aim of re-evoking the emotion. The exact way to recall past events can vary. Common recall practices include *thinking* about the event [9], *writing* about it [3, 31, 35], *drawing* or illustrating it [32], and *talking aloud* about the event [55]. ABR is claimed to be superior to other induction techniques [9, 12, 25]. It is not dependent on additional materials such as videos or images [9]. Moreover, the emotion is not induced by external stimuli, which might affect participants differently, but through personal experiences which are assessed by the participants themselves as eliciting the respective emotion [9].

2.3 Emotion Elicitation in Virtual Reality

Emotion elicitation has many applications and benefits in virtual reality. VR is a cost-effective way to build controlled environments [33, 41], and allows for replication of scenarios that would be difficult to generate in the real world [33, 40]. In some cases, VR can even outperform classical emotion elicitation techniques, as the higher level of immersion compared to other technologies can lead to a “more reliable elicitation of emotional experiences” [47] and it also serves as a safe platform, especially important for negative target emotions. A meta-analysis revealed that VR can be an effective tool to induce emotions in lab settings, particularly stress and anxiety [14]. However, some studies struggled with eliciting sadness and anger, reporting either no emotional changes or only brief emotional changes [14].

A few studies have explored autobiographical recall in VR. Baños et al. [5] studied five different emotion induction methods, including ABR in which participants were asked to talk aloud about their experiences in a virtual park. The results showed that the elicitation methods were successful. In another study, Fernandez-Alvarez et al. [17] investigated the effects of ABR in virtual reality on individuals with depressive symptoms, with the aim of training positive memory recall. Their participants were asked to *think aloud* about an intense and positive experience at a specific location to which they were transported and walked around in VR using Google Earth. The results showed positive short-term mood changes, but the effects wore off after a few days. Rivu et al. [40] compared four emotion elicitation methods between VR and the real world, including a *think-aloud version of ABR*. The elicited emotions were equally strong in VR and the real world. However, their participants were divided on how they felt about ABR in virtual reality, and the authors suggested further research on ABR methods in VR.

2.4 Summary and Research Gaps

Previous research shows that ABR is an effective emotion elicitation method, with a range of different implementations. Existing applications of ABR in virtual reality suggest that at least some ABR methods are effective in VR. However, three important gaps remain: 1) There are some implementations of ABR that have not been investigated in VR, such as recalling past events by writing or drawing about them. 2) Past research has overlooked the user experience and comfortability of ABR methods. This is important because ABR involves personal and potentially sensitive subjects, and ABR can be used in potentially sensitive settings like therapy. 3) We currently lack comparative studies where multiple virtual ABR methods are investigated, so we lack an understanding of their relative effectiveness and their individual strengths and weaknesses. In this paper, we close these gaps.

3 STUDY

We conducted a VR user study where we explored four different methods of ABR to understand their effectiveness and user experience. We received an ethical approval from the ethics board of the Faculty of Mathematics, Computer Science and Statistics at LMU Munich (EK-MIS-2021-050).

3.1 Study Design

We conducted a within-subjects study with the following independent variables:

Autobiographical Recall Method (4 levels) Talking to an artificial avatar; Talking to an avatar as proxy for the researcher; Thinking quietly; VR pen (used for writing and drawing)

Emotion (4 levels) Happiness; Sadness; Anger; Fear

To cover all combinations of independent variables, we applied a Graeco-Latin Square design, counterbalancing the 16 conditions. Thus, each participant applied each recall method and elicited each emotion, but only experienced four of 16 conditions. We selected these four emotions as they belong to the set of *basic emotions* [16] and they have been identified as suitable for ABR [45].

3.2 Participants

We recruited 17 participants for the study (6 female, 11 male). Participants were recruited through social media channels and internal university channels. They were between 21 and 57 years of age (Mean = 28.47, SD = 8.581). The participants had diverse levels of VR experience: two had no prior experience with VR, six had little experience, two were moderately experienced, three had much experience, and four reported having very much experience. Regarding emotion elicitation methods, 14 participants claimed having no experience and three reported having little experience.

3.3 Autobiographical Recall Methods

We developed four virtual ABR methods for our study. They were chosen and developed based on existing ABR techniques used in the real world (*thinking quietly* [9], *thinking aloud* [55], *writing* [3, 31, 35], *drawing* [32]), the requirements of the virtual context, and early pilot testing. We describe the four methods below. The elaboration always took place in private, i.e., no researcher was present and no oral or written information was recorded.

3.3.1 Talking to an Artificial Avatar. In this method, the induction of the target emotion is achieved by the participant speaking aloud to a virtual agent. We used this method because participants may rely on the social aspect associated with the presence of an interlocutor, but at the same time may be reserved about sharing private experiences with a stranger (e.g., the researcher). Several studies have confirmed the effectiveness of such agents, for example, in building trust in online retail [11] and in supporting teaching [30]. Furthermore, virtual agents have been used to accompany patients with post-traumatic stress disorder during home-therapy and assist them in the recollection of memories [48]. Thus, we believe that virtual agents also offer great potential for the application in emotion elicitation through the recall of personal experiences. The avatar was in a continuous idle animation loop with minor, natural movement, including blinking, head tilting, and arm movement. During elaboration, the avatar focused on the participants.

3.3.2 Talking to an Avatar as Proxy for the Researcher. This method aims to evoke the target emotion by having the participant speak aloud to an avatar, but this time the participants believe that the avatar is connected to the researcher who embodies the avatar and is present in the virtual environment (VE) listening to what the participants say. This allowed us to understand whether users respond differently to two types of virtual avatars for ABR, where one has a human connection and one is purely artificial. For example, the human component might make the situation more natural for some, but it might also make users more reluctant to share private experiences. This understanding is important because both computer-controlled and user-controlled avatars are key aspects of VR. We apply the ‘inverted Wizard of Oz paradigm’ [7]. The interlocutor (the avatar) is a computer, but is presented to participants as a real person. This deception maintains privacy while we assess perceived differences in experience and elicited emotions when participants believe someone is listening and when they believe no one is listening. Participants were debriefed on this after the study.

The proxy avatar was in the same idle animation loop as the artificial avatar, but head movements were varied (e.g., different types of nodding and tilting). They were triggered on specific keywords when detected in the participants’ narratives to convey the feeling that the avatar was controlled by a real person. We included thirty most common words in the English language [1] (the thirty most common words in spoken German [54] respectively), as well as words referring to our target emotions, e.g., “angry”. Keywords were detected through the Windows Speech DictationRecognizer¹. To prevent reactions being triggered too frequently, a threshold of seven seconds between reactions was imposed.

3.3.3 Thinking Quietly. In this method, the target emotion is generated by quietly thinking about the past experience. This approach is attractive because it is very simple to set up, requiring no external functionality or assets (as opposed to, e.g., a virtual agent or a writing/drawing mechanism). Thinking quietly about a personal event is also beneficial when participants are reluctant to express out loud certain aspects of the experience. Thinking quietly is also a reasonable approach in scenarios where elicitation is done in a group of people [3].

¹<https://docs.unity3d.com/ScriptReference/Windows.Speech.DictationRecognizer.html>

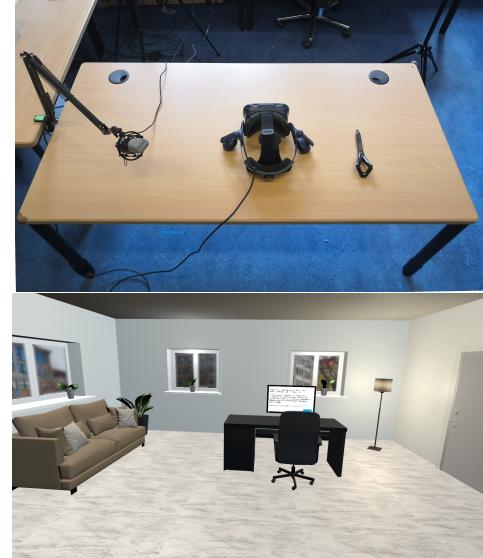


Figure 2: Real-world and virtual study environments. Top: Lab study set-up. Participants sat at a table that was exactly matched with the table in the virtual environment. A microphone was attached to the table, that was used to trigger avatar animations when certain keywords were detected. Bottom: The virtual environment. Participants sat on the chair, facing the computer screen.

3.3.4 Writing/Drawing. In this method, which is novel for VR, emotions were evoked using a VR pen, the Logitech VR Ink². Our original intent was for the participants to write a coherent text, as is often done in related studies [3, 31, 35]. However, our pre-tests with several participants showed that the VR pen is less suitable for this scenario, as participants found it too cumbersome (i.e., it takes more time than writing with pen and paper). The pilot participants preferred to depict past events in the form of key points, as drawings, or as a combination of the two. Because there was no clearly preferred approach, we allowed both writing and drawing in this method.

3.4 Apparatus

3.4.1 Set-Up. The virtual room was created using Unity 2019.4.5f and consisted of a desk, a chair, a monitor, a couch, some windows, plants and a lamp (Figure 2). In the real world, participants sat on a chair at a desk to match the visible virtual experience with the haptic experience in the real world. In addition, the desk was used as a writing surface. The avatar in the two talking methods was taken from Microsoft’s Rocketbox avatar library³. The avatar’s animations were custom-made and implemented using both Blender and Unity. The technical set-up consisted of an HTC Vive Pro, BaseStation 2.0, a microphone, and the Logitech VR Ink. Programming was done in C#.

²<https://www.logitech.com/en-us/promo/vr-ink.html>

³<https://github.com/microsoft/Microsoft-Rocketbox>

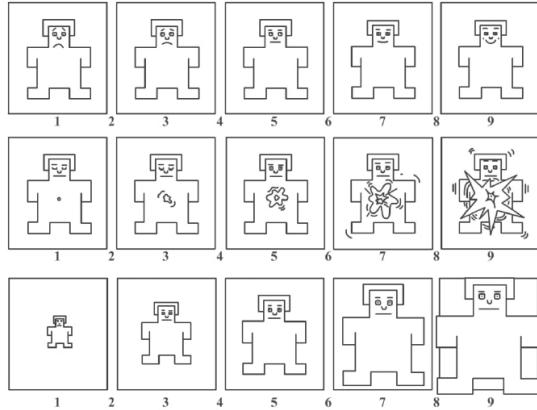


Figure 3: Self-Assessment Manikin [46] used in the study. The top row represents the valence dimension, the middle row the arousal dimension, and the bottom row the dominance dimension.

3.4.2 Measures and Materials. The study included both standardized and custom questionnaires and included external materials.

The standardized measures were:

Self-Assessment Manikin (SAM) The SAM scale (see Figure 3) is a brief pictorial self-report instrument for emotional states in the dimensions of valence, arousal, and dominance (VAD). It can be easily understood and used across cultures [6] and has been used in numerous studies (e.g., [2, 10, 53]).

Ten Item Personality Inventory (TIPI) The TIPI [20] is a concise measure for assessing the dimensions of the Big Five personality model. This instrument was used to determine whether personality factors influence the preference of ABR methods and the ability of ABR methods to elicit emotion.

Igroup Presence Questionnaire (IPQ) The IPQ⁴ measures the participants' presence, that is, their sense of being in the virtual world. We used this to determine if presence influences the efficiency of different recall methods.

The custom measures were:

Demographics Questionnaire We asked participants about their age, gender, and highest level of education. Furthermore, we inquired about their experience with VR and emotion elicitation methods.

In-VR Questionnaire For each ABR method, we asked about how comfortable participants felt using the method, and how easy it was for participants to reflect on past experiences when using the method. This was done within the VR environment after each elicitation round.

Post-VR Questionnaire This questionnaire asked for preferences regarding the four ABR methods, and participants could provide feedback on their experience with the application and task.

⁴<http://www.igroup.org/pq/ipq/index.php>

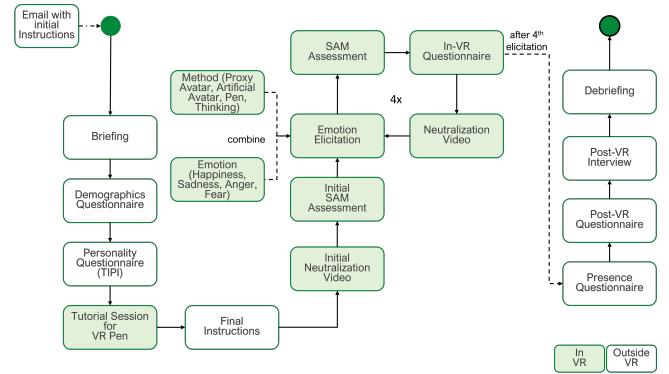


Figure 4: Overview of the study procedure.

Semi-structured Interview The goal of the interview was to find out what participants particularly liked or disliked about each ABR method, how comfortable and easy it was for them to elaborate on past experiences, and whether they were able to focus on elaborating on the experience. We also asked participants to rank the methods based on their preference for future ABR tasks. In addition, we asked about more general aspects, such as how easy it was to find past experiences related to each emotion and overall comfort with elaborating on past experiences.

The external materials were:

Avatars We selected a female avatar from the *Microsoft Rocketbox Avatar Library* [19]. This avatar was used in both avatar methods to ensure comparability between the methods. The avatar could only react through upper body movements (i.e., it does not speak). The difference between the two methods involving the avatar is reflected in the respective animation. While the artificial avatar uses only idle animation, the proxy avatar changes their animation when participants use certain keywords while speaking.

Neutralization Videos Based on recommendations by Riva et al. [40], we included a neutralizing factor prior to each elicitation round. This is done to ensure that previously elicited emotions are neutralized and do not interfere with any subsequent elicitation rounds. We incorporated four non-verbal videos validated to induce neutral emotions taken from the *mixed emotions film library* [44].

3.5 Tasks

Each participant completed four recall tasks, each associated with a different ABR method. The participants were asked to recall four events from their lives, one of which evoked happiness, one of which evoked sadness, one of which evoked anger, and one of which evoked fear. The concrete task was formulated based on Mills and D'Mello [31] and stated: "Please recall in detail the one situation that has made you the most happy/sad/angry/scared you have been in your life, and talk/think/write (or draw) about it such that it evokes the same emotion again".

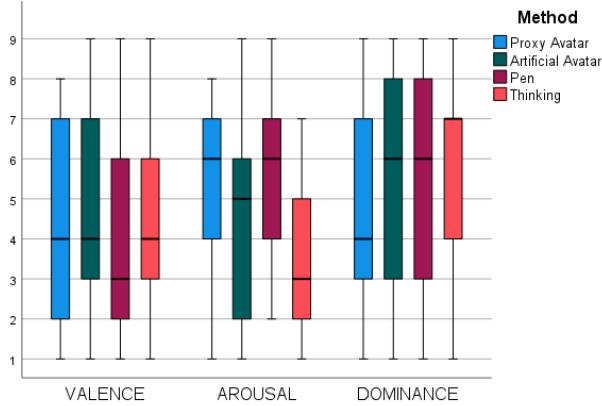


Figure 5: Boxplots of all VAD ratings per recall method. The Y axis represents the SAM value. No statistically significant differences were found between any of the ABR methods in any VAD dimension.

3.6 Procedure

The procedure is illustrated in Figure 4. The study was conducted in a lab at a university building. Prior to the study, participants were informed by email of the broad aims of the study and were asked to already identify memories for the four target emotions.

Upon arrival, participants were briefed about the study and asked to sign a consent form. Participants then completed the demographic questionnaire and the TIPI on a laptop provided to them. Following this, participants completed a brief VR training session to familiarize themselves with the functionalities of the VR pen.

In the main part of the study, the researcher was absent and the participants' narrations were not recorded to ensure privacy. Participants first viewed an introductory screen in VR, watched an initial neutralization video, and completed the first SAM scale. Then, four emotion elicitation rounds followed. Each round included a different ABR method and target emotion, and consisted of four steps: 1) participants elicited the target emotion using the assigned ABR method, 2) participants filled in the SAM scale, 3) participants completed the in-VR questionnaire, 4) participants watched a neutralization video. The last step was omitted in the final round.

After the four elicitation rounds, participants took off the HMD, and completed the presence questionnaire and the post-VR questionnaire using a laptop. Afterwards, we conducted the semi-structured interview. Finally, participants were compensated for their time. Each session lasted on average 60 minutes.

4 RESULTS

4.1 Effectiveness of the Methods

The SAM scale results reveal how effectively the four ABR methods could elicit the target emotions. First, we conducted a Friedman test for each VAD dimension from all emotions merged together, to assess differences in how the four methods of ABR affect these dimensions (Figure 5). No significant differences were identified in any dimension (valence: $p = .916$, arousal: $p = .6$, dominance: $p = .71$). When comparing medians, the *Thinking Quietly* method seems to induce lower arousal, and the *Proxy Avatar* method lower dominance than other methods.

Second, we compared each emotion individually between the ABR methods, to gain a more thorough understanding of the possible differences. For this, we applied the Fisher-Freeman-Halton exact test (Figure 6). There were no statistically significant differences between any of the VAD dimensions in any of the emotions ($p > .05$), leading to the conclusion that all methods successfully and equally induced changes in the VAD dimensions.

Third, we merged the ABR methods together and compared the overall VAD values between emotions. We did this to investigate whether some emotions were stronger than others. Applying Friedman test, we identified significant differences between the emotions in valence ratings ($p < .001$) yet no significant differences for arousal ($p = .864$) and dominance ($p = .122$) dimensions.

4.2 Correlations

We assessed whether age, gender, VR experience, personality dimensions, sense of presence, and time spent on the elicitation influences the ability of a method to elicit changes in VAD dimensions. To do so, we applied the Kruskal-Wallis Test for VAD ratings within each of the 16 conditions. However, no significant differences were found for any of these factors ($p > .05$). Moreover, we tested for differences in preferences for ABR methods that could be attributed to the Big 5 personality dimensions. Except for a correlation between the artificial avatar method and the personality factor Agreeableness ($p = .022$), no other differences were found ($p > .05$).

4.3 Perception of Methods

After each emotion elicitation method, participants rated how comfortable they felt about the method, and how easy it was for them to reflect on past experiences through this method (Figure 7). In addition, participants gave detailed feedback about each method in a semi-structured interview. Below, we report these results.

4.3.1 Artificial Avatar Method.

For this method, most participants reported that they were comfortable and could focus on talking about their past experiences. Nine participants liked the fact that there was no real person listening, which allowed them to talk about their private experiences without hesitation and without fear of keeping someone waiting while thinking about what they wanted to say next. P14 explained: "*it felt like I could tell everything and nobody was judging me*". Ten participants liked the movements of the avatar, since they gave the impression that the avatar was listening, they appeared realistic and human-like, but were subtle enough not to distract participants. Furthermore, the avatar was mentioned as an anchor point keeping participants focused on talking.

On the other hand, five participants did not like the feeling of talking only to themselves or "into the void". P04 stated: "*I had this feeling of, I am seeing this avatar, but actually in real life, I'm just talking to the wall*". Four participants criticized the lack of a human interlocutor to talk to, as they missed some aspect of human interaction and feedback, making it difficult for them to speak. This was also mentioned as the reason for three participants not to feel comfortable with this method. Three participants thought that the avatar's movements were unnatural (e.g., too repetitive).

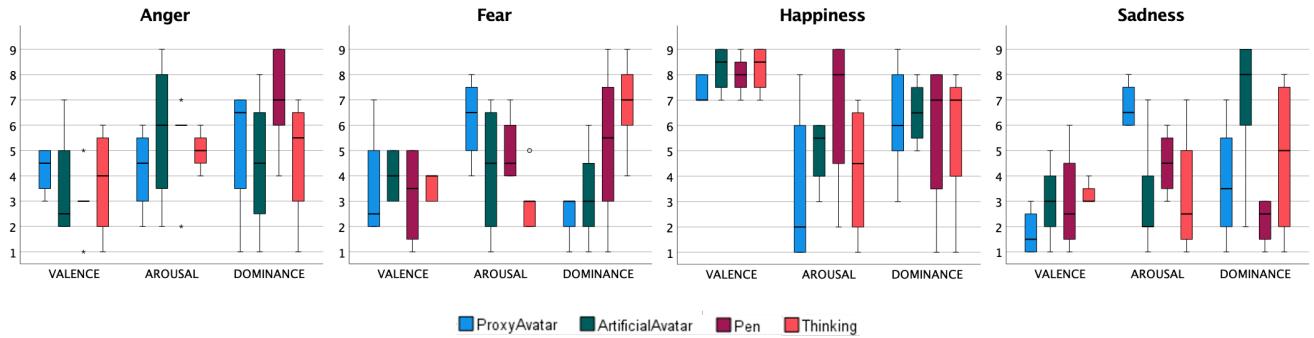


Figure 6: Boxplots of VAD ratings per emotion across recall methods. The Y axis represents the SAM value.

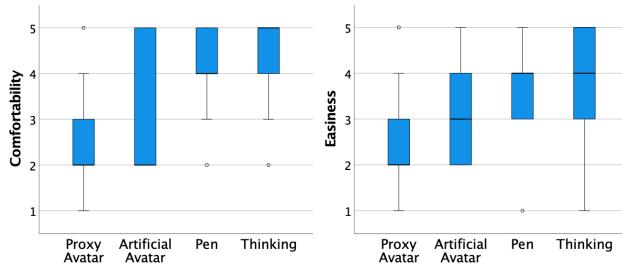


Figure 7: Boxplots for comfort and easiness ratings across elicitation methods.

4.3.2 Proxy Avatar Method.

For this method, ten participants reported feeling completely or moderately comfortable speaking about past experiences. Three participants liked that the avatar was more interactive as it nodded at the right moment and seemed attentive. Moreover, most participants found it easy talking to the proxy avatar, and they could focus well on their elaboration. Reasons given were that it made sense to talk because someone was listening, it felt less like talking "into a void", and the avatar's behavior facilitated talking.

Seven participants did not feel comfortable, the main reason being that they found it unpleasant that the researcher listened in the background when speaking about private topics. The listening factor was also mentioned as making talking freely more difficult. A few participants found it difficult that they could not see the person listening and/or not being sure who was listening. Some of them stated that they would have preferred to talk to a person face to face or at least over a voice channel. Furthermore, for some it was challenging to focus due to a perceived pressure to maintain the flow of the conversation, as they wanted their elaborations to be easy to follow. Although not a negative aspect per se, eight participants did not actively notice a difference between the movements of the proxy avatar and the artificial avatar.

4.3.3 VR Pen Method.

All participants reported feeling comfortable and most found it easy to elaborate on past experiences using this method. Reasons given for the high level of comfort were that participants knew that none of what they produced would be stored, and that they could keep the narrative structured. Maintaining a structure was

also named as a factor that minimized the risk of losing one's train of thought, allowing the majority to focus well on their elaboration. P06 explained: *"To draw and write helped me focus and it helped get into that scenario again in my head, to really envision what it was like."* Five participants appreciated the option to choose between writing keywords and drawing. P03 stated: *"Sometimes you don't find the words, so you draw. Sometimes you don't know what to draw, so you write keywords if you can't form full sentences. Maybe because the emotion is very strong at the moment, you can't find the right words. Drawing allows to exteriorize the feelings. It's very helpful."*

However, three participants could not imagine that emotions can be evoked as much by writing/drawing. P12 said that it was *"not like something that was intuitive for me, for this task, to think about an emotion with a pen."* Three participants found it difficult to accurately represent the situation with the pen, due to not being good at or used to writing about or drawing emotional content, or because they found it more difficult compared to writing with a real pen and paper.

4.3.4 Thinking Quietly Method.

All participants reported feeling comfortable and most reported it being easy to quietly think about past experiences. Eight participants liked that they could just go over their experiences in their minds, and that it was completely private without having to produce anything written or verbal. P08 explained it as follows: *"I could just focus very clearly on the emotion and had no fear of something that I'd rather not tell or anything getting out and so I could just immerse myself into the emotion and all the facts around it which made it easy to recall it."* The majority of participants were able to focus well on their private experience. P01 reported: *"Being in a virtual environment takes away the disturbances from the real world. I think, if you're in a calm space in the virtual environment, it's also easier to calm down and think about your emotions."*

However, six participants reported having trouble recalling the memory and emotion again. P02 explained: *"You're not really getting into the situation as much as if you talked about it, which is for me good because it was sadness and I don't really want to go back to that situation. So if you want to go back I would say it's a negative thing, but it depends [on] how you see it."* Another negative aspect mentioned was a lack of focus and concentration for five participants. In their opinion, thinking quietly made their thoughts drift and made it easier to lose the structure of the elaboration.

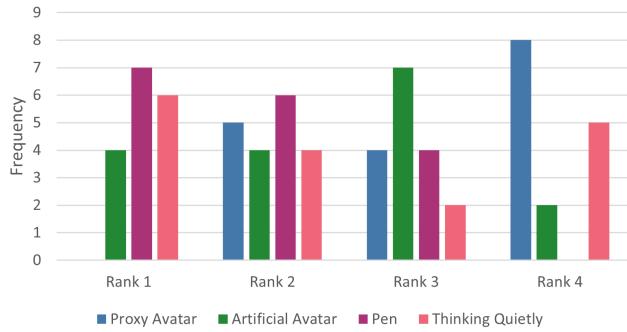


Figure 8: Preference ranking of elicitation methods from most (rank 1) to least preferred (rank 4).

4.4 Ranking of Virtual ABR Methods

We asked participants to rank the methods by preference (Figure 8). Participants could rate methods equally, in which case each equally rated method received the same corresponding rank.

The Pen method was rated most favorably, followed by the Thinking Quietly method. The Avatar methods were rated less favorably; however, the Artificial Avatar method was still noticeably better rated than the Proxy Avatar. Interestingly, the Proxy Avatar method was never ranked as the most favored method and the Pen method was never ranked as the least favored one.

4.5 General Feedback on ABR in VR

Ease of Finding Experiences. All but three participants reported facing at least some difficulty in coming up with past experiences. Many were uncertain about which memory would work most effectively. For happiness and sadness, participants had difficulty picking one experience because of the many experiences they had. For anger, repression of the experiences was mentioned as a factor. Regarding fear, some mentioned not experiencing this emotion often. Still, participants said that it was helpful to be informed in advance, to find experiences that evoked the target emotions.

Jumping Between Experiences. Most participants did not experience their thoughts drifting back to a previously recalled memory. Five participants reported that this happened at some point. Reasons were that two experiences were related, the lack of focus during the thinking quietly method, and the strength of a previously evoked emotion that shadowed the current elaboration.

Distractions. In terms of distractions within the virtual environment or from outside, eight participants reported not being distracted, in part because the virtual environment was perceived as neutral. Other participants were slightly distracted by minor things, like the unfamiliar behavior of the VR pen, the VR equipment, and the novelty of the virtual environment and artifacts such as the avatar.

Further Remarks. The neutral environment was mentioned as an aspect that made it easier to detach from real life and thus better focus on the task. Some participants wished to have the task conveyed in ways other than through the virtual screen, for example, through the avatar.

5 DISCUSSION

In this section, drawing on our quantitative and qualitative results, we discuss our findings.

5.1 Autobiographical Recall Methods in VR

All four methods were capable of eliciting emotions, with little to no significant differences between them in any of the VAD dimensions. This suggests that all of the methods can be applied in VR and that they are comparable in effectiveness. We believe that this is great news, as ABR can therefore be adapted in a wide range of scenarios. However, some ABR methods were more preferred than others, and there are individual considerations for each method.

Generally, *Writing/Drawing* was the most preferred method, followed by the *Thinking Quietly* method. Participants felt very comfortable with these methods and felt they were easy to use, although *Writing/Drawing* did require an initial introduction. These methods might therefore be the safest options when the users' preferences are unknown, or when there are other limitations that prevent the adaption of ABR to the user's needs (e.g., time limits). It is also notable that the *Thinking Quietly* method is considerably easier to implement than the other methods, as it does not require any distinct functionality to work.

Even though the avatar methods were generally less preferred, some users still liked the experience with avatars. For some, the avatar functioned as a point of focus when elaborating on past events. It might be that making the avatar more intelligent and advanced (e.g., varied responses to the user, more animations) would improve the experience further. The human proxy avatar was the least preferred method, and some participants felt uncomfortable talking to an avatar when they assumed that a human experimenter was listening to them. As suggested by some participants, establishing a clearer connection between the avatar and the human would likely make this method more comfortable (e.g., by adding a voice channel so that the human experimenter could respond to the user's elaboration through the avatar).

5.2 General Considerations for Implementing Autobiographical Recall in Virtual Reality

Based on our results, we present some design considerations for implementing virtual scenarios where ABR is used (e.g., user studies, therapy sessions, training).

5.2.1 Inform Users Prior to the Session. Participants generally struggled to find appropriate memories from their past, especially when associated with negative feelings. Since negative experiences are remembered more strongly and easily than positive ones [4], repression of negative experiences is unlikely to explain this phenomenon. It is more likely that participants have numerous memories for each emotion and, therefore, especially due to the wording of the task (i.e., *find the experience that evoked the emotion the strongest*), they faced difficulty in selecting an experience. Giving participants guidance in finding events, and giving them time to think about their memories and choose the appropriate memory, could mitigate this issue. In our study, we informed participants beforehand and asked them to think about suitable memories before they attended the study, and many participants found this helpful.

5.2.2 Limit the Number of Memories and Recall Independent Memories. Although rare, a few participants reported occasional involuntary return to a previous memory when elaborating on another. Some participants had similar experiences in the study by Rivu et al. [40]. Reasons given were that two experiences were linked, a low level of concentration, and an exceptionally strong expression of a previously evoked emotion. Limiting the number of target emotions and asking users to select memories that are not related might help minimize the likelihood of such issues.

5.2.3 Include an Emotion Neutralization Factor between Recall Sessions. If several emotions are targeted, it is crucial that users' emotions are neutralized before evoking further emotions. In our study, this was achieved through neutralization videos. Participants perceived the videos as a neutralizing factor and/or felt that the videos distracted them from the previously reflected experience so that they could focus on the next emotion. Occasionally, the videos evoked slightly negative or positive emotions. In general, a video with a slightly positive valence can be classified as a 'pleasant neutral movie clip' [38], which may be better than only neutral clips because they can attract more attention [38]. Also, the time spent on the questionnaires between recall scenarios likely helped, as it further allowed participants to take a break from eliciting emotions and focus on something else, as emotions wear off over time [40].

5.2.4 Allow Participants to Become Familiar with the Virtual Environment and Artifacts such as Virtual Agents. While the initial tutorial for the VR pen prevented confusion during the study, some participants reported that they were focused on the virtual environment and the movements of the avatar when they first encountered it, due to the novelty effect. To avoid such distractions and a possible resulting impairment in the elicitation of emotions, it may be advisable for similar studies to first familiarize participants with the virtual environment. It may also be that becoming more accustomed to a virtual avatar might make eliciting emotions in its presence more comfortable.

5.3 Limitations and Future Work

This study was limited by some factors. One of these aspects is the sample size ($N=17$). We did not identify factors, such as personality and sense of presence, significantly responsible for participants' preference for certain methods, nor for methods outweighing others in eliciting changes in emotion.

The avatar may also be a constraining factor. When ABR involves virtual agents, elicitation performance and user experience might be susceptible to the exact implementation of the agent, e.g., its appearance or animation. More advanced virtual agents could lead to more positive results. Similarly, establishing a channel for the researcher to really respond to the user in VR could improve the experience and also lead to additional insights.

In addition, our focus was on relative comparison between different ABR methods in VR, but not on comparison between real-world and virtual approaches. Although prior research has found similarities in emotion induction effectiveness between some ABR methods in the real world and in VR [40], future work could conduct an in-depth investigation of the effectiveness of the proposed ABR methods in VR compared to a real-world baseline.

Finally, an interesting aspect for future work could be the development of unconventional types of ABR in VR, such as re-enacting past events. Another promising method enabled by the Logitech VR Ink is drawing and designing in 3D, which has the potential to immerse participants more in past experiences and thus evoke emotions more effectively.

6 CONCLUSION

We investigated how various methods of autobiographical recall, an approach used effectively in real-world studies to induce emotions, can be applied in virtual reality. In particular, we were interested in how these methods perform in virtual reality and how they are perceived by users. We conducted an exploratory user study with 17 participants in which each of them went through four conditions, each a combination of one recall method and one emotion. The ABR methods we implemented were: 1) talking to a virtual computer-controlled avatar, 2) talking to a virtual avatar that was allegedly connected to the researcher, 3) writing/drawing with a VR pen, and 4) thinking quietly. The target emotions were happiness, sadness, anger, and fear. Our results show that all ABR methods similarly induced changes in emotional states, suggesting that all four ABR methods can be used in VR. Furthermore, participants tended to prefer the *Writing/Drawing* and *Thinking Quietly* methods compared to the *Avatar* methods. Still, all ABR methods have their own strengths and weaknesses, and the user's preferences could be accounted for when choosing the ABR method to be used. Our results are useful for the implementation of emotion research and emotion experiences in virtual reality.

ACKNOWLEDGMENTS

The presented work was funded by dtec.bw – Digitalization and Technology Research Center of the Bundeswehr [Voice of Wisdom].

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