University of Tartu

Faculty of Social Sciences

Institute of Psychology

Madli Kaljo

Comparison of psychedelic mixed reality experiences - an explorative study

Seminary work

Supervisors: Jaan Aru, PhD, Karl Kristjan Kaup, MSc, Madis Vasser, PhD

Running head: Comparison of psychedelic mixed reality experiences

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Abstract

The aim of this study was to investigate various psychedelic virtual (VR) and augmented reality (AR) experiences and compare perceived psychedelic effects they produced. A total of 24 participants (N=24) were exposed to 12 different experiences, including three VR, eight AR, and one baseline (AR) experience. Following each encounter, participants responded to a brief custom-made questionnaire assessing both psychedelic and affective dimensions of the experience. Mixed measures ANOVA revealed that six experiences, comprising three VR and three AR, exhibited significant differences from the baseline measure in terms of psychedelic effects. While VR experiences generally yielded higher results than AR experiences, not all of them differ significantly from three higher scoring AR experiences. SAM affective dimensions correlated significantly with overall psychedelic effect, correlation was weak to medium.

Keywords: psychedelic, virtual reality, augmented reality, cyberdelics

Psühhedeelsete liitreaalsete kogemuste võrdlemine - eksploratiivne uurimus

Kokkuvõte

Uuringu eesmärgiks oli testida psühhedeelseid virtuaal- (VR) ja liitreaalseid (AR) kogemusi ning võrrelda eri kogemuste tekitatud tajutud psühhedeelset efekti. Selleks näidati 24-le katseisikule (N=24), 12 erinevat kogemust, mille hulgas oli kolm VR, kaheksa AR ja üks baastaseme (AR) kogemus. Pärast iga kogemust pidid katsealused täitma uuringu tarbeks loodud küsimustikku, mis mõõdab kogemuste psühhedeelset ja afektiivset mõju. Uuringu käigus selgus, et kuus kogemust, sealhulgas kolm VR ja kolm AR kogemust erinesid tajutud psühhedeelsuse poolest statistiliselt olulisel määral baastaseme kogemusest. Üldiselt said VR kogemused AR kogemustest tugevamaid tulemusi, kuid üks neist ei erinenud kolmest kõrgema skooriga AR kogemustest statistiliselt olulisel määral. Kõik SAM afektiivse skaala dimensioonid korreleerusid üleüldise psühhedeelse efektiga statistiliselt olulisel määral. Korrelatsioon oli nõrk kuni keskmine.

Märksõnad: psühhedeelikumid, virtuaalreaalsus, liitreaalsus, küberdeelikumid

Contents

Alternative forms of reality

Simulated environments were developed far before the terms “virtual, augmented and mixed reality” were first used. In 1956 Morton Heiling developed a multisensory stimulation Sensorama which let people feel like they were “in” the movie. It simulated a real city environment. Users could ride through it on a “motorbike” while hearing the engine, feeling the vibration and smelling the motor’s exhaust. Later, in 1960 Heiling patented a head-mounted display and called it Telesphere Mask (The Franklin Institute, 2023). The term “virtual reality” was first used in 1987 by Jaron Lanier. He had set up VPL Research. The company pioneered research into virtual reality and 3D graphics and sold the first VR gear which included VR glasses and data gloves (Virtual Reality Society, 2017). The first augmented reality system was invented in 1966 by Ivan Sutherland. It used an optical see-through head-mounted display (Javornik, 2016). In 1994 Milgram and Kishino introduced a reality virtuality (RV) continuum. That has been used as a framework in virtual and augmented reality research. The continuum has been modified quite a bit with technological and scientific development. From this continuum comes the term “mixed reality” that contains both virtual and augmented reality (Skarbez, et al. 2021).

With time, technology has become cheaper and more available to the general public. That is one of the reasons why virtual and mixed reality has appeared more as a research method. It enables conducting experiments that may be too dangerous, expensive or otherwise unreasonable to enforce in real life. Virtual reality experiments could allow a more realistic environment than lab experiments and can be more valid than field experiments (Vasser et al, 2017). Also, virtual reality experiments are more standardizable, because every detail can be programmed to be exactly the same every time the experiment is being run. There are also fewer intervening

variables. Simulations of real-life experiments have been used in experiments before virtual reality. Events have been shown to subjects on a 2D computer screen, but virtual and mixed reality allow much higher levels of immersion and presence. When a picture is moving along with the head it requires cognitive, but also physical involvement (Vasser et al, 2017).

Using technologies in personal and spiritual growth practices is quite common. Guided meditation on mobile apps, neurofeedback, brain-stimulation devices and computer-controlled light machines are some examples of that (Hartogsohn, 2023). Mixed reality as a therapy form is most researched in exposure therapy to treat anxiety and phobias (Aday et al. 2020). It has also been researched to treat depression (Kaup, et al. 2023) and applied within neurosurgery for presurgical planning and intraoperative navigation. The integration of mixed reality simulation into resident training has been identified as a potential opportunity for improving neurosurgical education (Paro, Hersh & Bulsara, 2022).

Psychedelics

Psychedelics are a class of psychoactive substances used throughout human history for religious and recreational purposes (Vollenweider, 2001). They can alter perception, mood and cognitive processes (ADF, 2023; Tulver, et al. 2023) causing different sensory hallucinations (Drew, 2022) and mystical experiences, but also psychosis (Vollenweider, 2001). Modern psychedelic research started in 1938, when Hofmann first synthesized lysergic acid diethylamide (LSD) (Doblin, et al. 2019). The term was introduced by Osmond in 1957 (Osmond, 1957) meaning “mind-manifesting”. Psychedelic compounds can occur naturally in plants (mescaline, DMT) and fungi (psilocybin) or can also be produced artificially (Vollenweider, 2001).

Psychedelics can be classified by their chemical structure or primary mode of action. Serotonergic hallucinogens (psilocybin, LSD and mescaline) act upon 5-HT1, 5-HT2, 5-HT6 and

5-HT7 receptors, partly upon the dopamine receptors D1 and D2 and the adrenergic α2 receptors (Vollenweider, 2001).

Serotonergic psychedelics primarily exert their effects through serotonin, particularly by acting as agonists at the 5-HT2A receptor (2AR) (Drew, 2022; Madsen et al., 2019). The 5-HT2A receptors are widely distributed in the central nervous system, with a prominent presence in brain regions crucial for learning and cognition (Zhang, Stackman Jr., 2015). While 5-HT2A receptors are distributed throughout the brain, a significant concentration is found in the cerebral cortex, especially layers I and IV–V (Zhang, Stackman Jr., 2015; Xu and Pandey, 2000; Hannon and Hoyer, 2008). They are also present in the piriform and entorhinal cortex, the claustrum, endopiriform nucleus, olfactory bulb/anterior olfactory nucleus, brainstem, limbic system, and basal ganglia, especially in the Nucleus Accumbens (NAc) and caudate nucleus (Zhang, Stackman Jr., 2015; Xu & Pandey, 2000; Hannon and Hoyer, 2008). Additionally, they are found in the visual cortex and at the terminals of axons reaching areas beyond the cortex, including the thalamus (Drew, 2022)

Research, primarily conducted on animals such as rats, mice, rabbits and primates, has indicated that 5-HT2ARs play a crucial role in various cognitive processes (Zhang, Stackman Jr., 2015). After the ingestion of psychedelics, sensory areas exert a greater influence on overall brain activity (Drew, 2022). This alteration not only affects perception but also impacts cognition (Carhart-Harris & Friston, 2019). Common effects of psychedelic substances include distorted perception, increased body temperature, euphoria, rapid breathing, and difficulty concentrating (ADF, 2023).

Activation of 5-HT2ARs has been associated with cognition-enhancing and hallucinogenic properties (Zhang & Stackman Jr, 2015; Majic, et al. 2015). Recent evidence

suggests that stimulating 5-HT2ARs may contribute to experiencing visual hallucinations by increasing neuronal excitability and altering visual-evoked cortical responses (Kometer et al., 2013). The 5-HT2AR is thought to hold special significance as one of the substrates through which serotonin regulates learning and memory (Menses, 2007). Notably, a study by Fisher (2019) demonstrated that psilocybin occupied a substantial portion, up to 72%, of 2AR receptors in the brain. The intensity of the psychedelic experience correlated with the occupancy of these receptors.

Vollenweider (2022) proposed that a key mechanism of action for psychedelic substances might involve the thalamic gating model. In this model, the cortex regulates thalamic information processing through axons expressing 5-HT receptors. Psychedelics disrupt the thalamic filtering system, allowing more sensory signals to reach the cortex. Essentially, psychedelic substances enable a greater amount of sensory information to pass through the thalamic filter and reach the cortex.

Carhart-Harris and Friston (2019) have proposed relaxed beliefs under psychedelics and the anarchic brain (REBUS) model that builds on the entropic brain hypothesis and free energy principle. The entropic brain hypothesis (Carhart-Harris, 2018) proposes that the quality of any given conscious state can be measured through a quantitative measure of entropy. Entropy is the index of spontaneous brain activity that represents the richness of the consciousness state that can be measured in electrical potentials recorded with EEG or MEG. According to the REBUS model psychedelics relax the precision of high-level priors or beliefs, liberating bottom-up info flow (Carhart-Harris, Friston, 2019).

How psychedelic compounds affect the brain has been studied using fMRI, and most of the studies have been conducted using resting state fMRI. It is found that psychedelic substances

affect how brain regions communicate with each other. Brain regions whose activity is normally coupled become less coordinated and the regions that are only loosely connected start to communicate more with each other (Drew, 2022). However, such neuroimaging studies have been with a small sample and results have been inconsistent (Drew, 2022).

Girn et al. (2022) analysis of existing fMRI data supports the REBUS model. They found that serotonergic hallucinogens (LSD and psilocybin) compress the usual hierarchy of connectivity between sensory and association networks. Sensory areas and their processing of the external world become less separate from abstract thinking and beliefs.

Common aspects of psychedelic experiences

To compare the psychedelic effect of different experiences, firstly it is necessary to define what is a psychedelic effect and what it consists of. According to literature psychedelic experience includes different psychosomatic feelings and philosophical understandings shown on table 1.

Table 1. Common effect of psychedelic experiences according to previous research.

Aspect	Meaning	Source
Ineffability	cannot be encapsulated in words	MEQ30 (MacLean et al., 2012; Barrett, Griffiths, 2018); PIQ (Davis et al. 2021)

Sacredness	A sense that what is encountered is holy or sacred, feeling of awe	MEQ30 (MacLean et al 2012; Barrett, Griffiths, 2018), PIQ (Davis et al. 2019); 11D-ASC (Dittrich, 1998; Studerus et al., 2010); PCQ-26 (Brouwer, Carhart-Harris, 2021)
Positive mood	Feelings of joy, ecstasy, blessedness	MEQ30 (MacLean et al., 2012; Barrett, Griffiths, 2018); APEQ (Wolff et al., 2022), Majic et al. (2015)
Tranquility	Peace and tranquility	MEQ30 (MacLean et al., 2012; Barrett, Griffiths, 2018); 11D-ASC (Dittrich, 1998; Studerus et al., 2010); PCQ-26 (Brouwer, Carhart-Harris, 2021); Majic et al. (2015)
Connectedness/ Unity	Being one with everything and everyone	MEQ30 (MacLean et al. 2012); Watts et al., 2017; EDI (Nour et al., 2016); PCQ-26 (Brouwer, Carhart-Harris, 2021); 11D-ASC (Dittrich, 1998; Studerus et al., 2010)
Ego-dissolution	Feeling like one does not exist.	EDI (Nour et al 2016); 11D-ASC (Dittrich, 1998; Studerus et al., 2010); Majic, et al. 2015

Disembodiment	Feeling like one does not have a physical body.	11D-ASC (Dittrich, 1998; Studerus et al., 2010)
Transcendence of space and time	Conventional time and space disappears	MEQ30 (MacLean et al., 2012; Barrett, Griffiths, 2018); PCQ-26 (Brouwer, Carhart-Harris, 2021)
Noetic quality / Revelation	Insight into the depths of some fundamental truth. Feeling of objective re	MEQ30 (MacLean et al., 2012; Barrett, Griffiths, 2018); PCQ-26 (Brouwer, Carhart-Harris, 2021); 11D-ASC (Dittrich, 1998; Studerus et al., 2010)
Apophenia	Tendency to perceive a connection or meaningful pattern unrelated or random things.	Evans et al. 2023; Luke, 2012; Preller et al. 2017
Introspection	Self-examination, observation of one's own mental and emotional processes	APEQ (Wolff et al., 2022); PIQ (Davis et al., 2021); PCQ-26 (Brouwer, Carhart-Harris, 2021), Majic et al. 2015
Thoughts of death	Thinking about death.	PIQ (Davis et al., 2021), Majic, et al. 2015

Cyberdelics

Psychedelics and virtual reality are similar due to their ability to exceed the limitations of typical consciousness. That is why they are often used together by recreational users to enhance the experience. Because of their ability to alter perspective and break patterns of everyday experience they can be used therapeutically (Aday, et al. 2020) as well as amplify the outcomes with mental health treatments (Wright, 2014). Interestingly psychedelic therapy and VR therapy have been suggested to treat the same types of mental disorders: depression and anxiety for example (Gomez-Busto and Ortiz, 2020). Prior studies have shown VR-mediated exposure therapy rather successful with effect sizes varying (Aday, et al. 2020). Psychedelic experiments have given contradictory results and critics consider it dangerous. Experiments that are too dangerous in the real world can be imitated in virtual reality (Vasser et al. 2017). Psychedelic virtual reality has been tested on subjects with depressive symptoms. After a two day intervention a significant improvement was recorded with an emotional state questionnaire (Kaup et al. 2023).

Cyberdelics are an umbrella term for technologies made to evoke altered states of consciousness similar to psychedelic drugs. The word consists of two parts “cyber” stands for cybernetics and “delics” refers to “mind-manifesting” psychedelic substances. Cyberdelic media opposes contemporary digital media on some pernicious effects: provoking FOMO (fear of missing out), anxiety and depression. That way digital technologies can be re-imagined. Advocates speak of the need for creating technologies that steer humanity away from mindless consumerism and distractedness (Hartogsohn, 2023).

Cyberdelics have been tested also by Rastelli et al (2022) who compared cognitive flexibility results after watching virtual reality panoramic views of nature and their counterparts

with DeepDream modified hallucinations: DeepDream is a computational procedure for altering images to make them visually similar to psychedelic hallucinations. They found indications that modified hallucinations enhanced cognitive flexibility (Rastelli et al. 2022) similar to psychedelic drugs (Pacheco, et al. 2023).

The objective of current study was to explore psychedelic and affective characteristics of different psychedelic virtual and augmented reality (cyberdelic) experiences. Additionally, the study aimed to compare these experiences to identify those that elicit effects similar to psychedelic drugs, emphasizing perceived psychedelic effects.

Method

Sample

Twenty four volunteers (N = 24) (twelve men, twelve women) ranging in age from 19 to 53 participated in this study. Participants were recruited in a snowball sampling method that started from social media platforms and psychology students' mailing lists. Between subjects, one gift card was drawn out. Eligible subjects had to be voluntary, adults, healthy and with normal or corrected-to-normal vision. Subjects had to confirm that they nor any of their close relatives have had psychotic episodes or schizophrenia, otherwise they would have been removed from the experiment. They also had to report not having motion sensitivity to participate. All subjects provided informed consent where study purposes, nature and possible inconveniences are introduced. When the subject has familiarized themself with this information and confirms that they do not have any of the contraindications. All the participants who started the experiment decided to go through with it. This research was done with dependent samples, where each participant underwent all the conditions, including the placebo condition. All the conditions except the placebo were presented in randomized order. This design was chosen to enable the evaluation of experiences without the influence of individual differences between subjects. Additionally, the use of dependent samples was deemed necessary due to the relatively small sample size (N=24).

Variables and measures

The experiment consists of 12 different interactive virtual reality experiences made specially for this study (see Appendix A). 11 effects simulated different aspects of psychedelic experience and one was a placebo. Each experience lasts for 3 minutes. All the experiences

excluding placebo were presented to a subject in randomized order. Placebo experience was the first that subjects experienced. With the A and B buttons on controllers participants could change the parameters of each experience (for example amplitude and speed of the effect movement). Parameters that can be changed vary across different experiences (see appendix A). With manipulating the characteristics of experiences subjects could adjust the experience to make it more or less intense and find their personal preferred configuration. These changes were recorded to find more common configurations among subjects.

For measuring the effects virtual reality experiences have on the subjects a custom-made questionnaire (see appendix B) was used. The questionnaire is identical for every experience during this experiment, meaning that every subject filled it 12 times. Questionnaire was inspired by Mystical Experience Questionnaire (MEQ30; MacLean et al., 2012), Psychological Insight Questionnaire (PIQ; Davis et al, 2021), Ego Dissolution Inventory (EDI; Nour et al., 2016), Acceptance/Avoidance-Promoting Experiences Questionnaire (APEQ,; Wolff et al., 2022) ja Altered States of Consciousness (11D-ASC; Dittrich, 1998; Studerus et al., 2010) questionnaires. Self Assessment Manikin (SAM - Bradley & Lang, 1994) was also used to measure affective impact of the experiences. As the subject answered the questionnaire after each experience, 12 times in total, the questionnaire could not be too long. In the experiment, we asked subjects demographic data and previous experience with psychedelics as well as experience with meditation since these aspects can alter their perception of psychedelic virtual reality. At the end of the questionnaire there was an option to voluntarily leave comments.

After the experiment, the subject filled out a follow-up questionnaire, which consisted of questions to ask about their personal data: age, gender and highest education obtained as well as previous experiences with psychedelic substances.

Aparature

The experiences were conducted using a commercial VR system: HTC Vive Pro headset and Valve Index controllers. The headset has 90Hz OLED screen, wide field of view (110 degrees) and high screen resolution (2160x1200). The experiment was run on a desktop computer (Intel Core i7, NVIDIA GTX 970 / AMD 290 graphics card or faster, 8gb of memory). Headset and computer were connected with the cable, because of the camera used for AR experiences, controllers were connected via Bluetooth.

Procedure

Subjects took part in a single session which lasted for approximately 1,5 hours and was held in the University of Tartu Computer Sciences Virtual Reality Lab. If the subject agreed to that the session was being recorded through the computer screen record using OBS Studio. Recording involved only what the subjects saw in their headset, subjects themselves were not filmed. Recording was necessary to keep the experiment conditions as similar as possible for each participant and to control the experiment conditions of the outliers. During the experiment session the subject underwent all the 12 experiences included in this experiment. Each experience lasted for 3 minutes, but if the subject wanted the experience was cut short. After each experience, subjects filled out a custom-made questionnaire (see appendix B) that let's compare experiences with each other. Questions were ordered randomly.

The first experience that the subject underwent was a placebo condition. That was for familiarizing the subject with virtual reality and the headset and also to see how participants interpret augmented reality without any added effects. In the placebo condition the subject saw the regular world through the camera of a virtual reality headset without any augmentation,

although with lower fidelity due to resolution of the camera. After the experience, the subject filled out a questionnaire. That was used as a baseline measurement. Subsequent experiences were presented to the subject in randomized order. After each experience the subject filled out the questionnaire and could rest as long as they wanted to. When the subject was ready the next experience was presented. After all the experiences were finished,the subject received the follow-up questionnaire (see appendix C) where the subject was asked about their personal data as well as previous experiences with psychedelics and virtual reality. After that the experimentator answers all the questions the participant might have and discusses the experience if the subject wants to.

ChatGPT 3.5 was used for language editing in this study.

Ethics

This research is approved by The Research Ethics Committee of the University of Tartu. Before the experiment subjects were informed about the methodology and possible side effects. Every single participant had to read and sign an informed consent agreement to participate in this study. Participating in this experiment was voluntary, the subject had the right to refuse participating or discontinue the experiment at any time. The experiment was recorded only when the subject approved of this. If the participant discontinued the experiment the recording was stopped and the subject had the right to ask to exterminate the recording.

Virtual reality is a non-invasive method. Across studies, it has been tested on thousands of participants and it has been found that it has not had significant negative side effects to any participants without contraindications. Empirically proven side effects of virtual reality is slight dizziness (Nichols & Patel, 2002), but technological improvements have minimized this side effect.

All the equipment that we use is commercially available, certified, patented and compliant with European standards. That means that stimuli with harmful parameters are precluded. Before the experiment starts the subject was briefed that if they experienced any side effects they can discontinue the experiment. During the whole experiment, the subject was monitored by the experimentator, who was ready to respond and help if the subject needed it.

Statistical analysis

The study aimed to assess various aspects contributing to the overall psychedelic effect instead of focusing on specific elements. The primary goal was to understand the general impact of the cyberdelic experiences. Participants completed a questionnaire after each of their 12 experiences. To prevent participant fatigue, the questionnaire was kept concise despite measuring multiple aspects of the psychedelic experience. Statistical analysis involved using JASP 0.16.3.0 and RStudio 23.09.1.

To compare experiences, averages of the responses were used, making the data suitable for repeated measures ANOVA. Most experiences skewness and kurtosis were between -1…1, only two experiences were outside of that criteria: MA (skew=1.117, kurtosis=-0.309) and KA (skew=-0.008; kurtosis=-1.239) (See appendix A). All the experiences fit into criteria of skewness and kurtosis -2…2 commonly used in social sciences. Otherwise, lowest scoring experiences (MA and TR, see appendix A) would have been nonparametric. The ANOVA test did not include SAM, UU and HIL questions (see appendix B). Bonferroni post-hoc test was executed because all experience comparisons are equally important. It's worth noting that the Bonferroni test has a higher risk of missing real effects (type II error). To address this, results were double-checked using the Holm test before drawing conclusions.

During the experience the program recorded every instance when the subjects changed the configuration of their experience (for exact breakdown of the configurations that subjects could manipulate see appendix A), saving the input values and durations of each configuration. From that data, manual binning of the preferred configurations of each participant in each experience resulted in two common configurations across all participants and experiences, leaving out some outliers, whose preferred configurations differed too much from other participants.

The questionnaire underwent evaluation through unidimensional reliability and principal component analysis. Principal component analysis was chosen over exploratory factor analysis due to the study's smaller subject pool (N=24) and the nonparametric nature of raw data. After reliability test questions with low item-rest correlation underwent serious considerations about their necessity and fit into the model of psychedelic experience. After that, two questions were excluded: UU and HIL (see appendix B). The baseline measurement MA was excluded from these analyses.

To further evaluate the questionnaire, correlation analysis was conducted by comparing comments and summarized questionnaire scores (excluding SAM, HIL and UU-questions). To facilitate this analysis, comments were encoded into a numeric scale using a binary system (0...1). If a comment described the experience as psychedelic or mind-altering, it received one point; otherwise, it received 0 points. The detailed coding schema can be found in appendix C. Subsequently, the sum of questionnaire scores was compared to comment points, considering only the responses from individuals who provided comments. Initially, two people were involved in interpreting the results, but one person later withdrew from their position.

In addition to the psychedelic effect questionnaire, the Self Assessment Manikin (SAM, Bradley & Lang, 1994) was used to examine the affectivity of various experiences. Correlation analysis was performed on SAM data to identify dimensions that coalesce and correlation with overall psychedelic experience. The SAM results, illustrating the affective impact of the experiences, can be found in appendix A. For correlation analysis Pearson's correlation was used, because raw data in all SAM dimensions and answer means in the questionnaire of overall psychedelic experience were normally distributed (Skew and kurtosis between -2…2 as commonly used in social sciences).

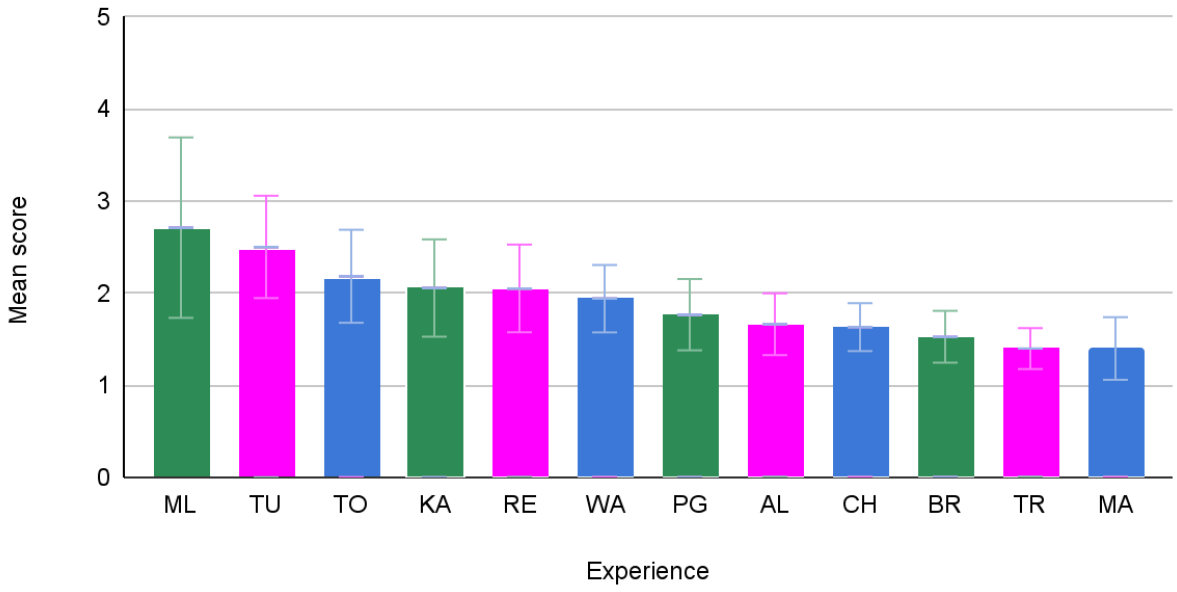
Results

Comparison of Experiences

To evaluate the psychedelic effect of the experiences, mean scores across all questions excluding UU and HIL in the psychedelic section of the questionnaire (see Appendix B) were analyzed. Figure 1 illustrates that VR experiences (ML, TU, and TO) obtained higher scores compared to AR experiences, with the baseline measure (MA) and TR experience (see appendix A) scoring the lowest.

Figure 1

Mean scores of overall psychedelic effect with standard deviations across all participants



Note. This table displays the mean scores and standard deviations for all experiences, irrespective of whether they significantly differed from the baseline measure. The statistical significance of these differences is not considered in this table; instead, it is addressed in Figure 2.

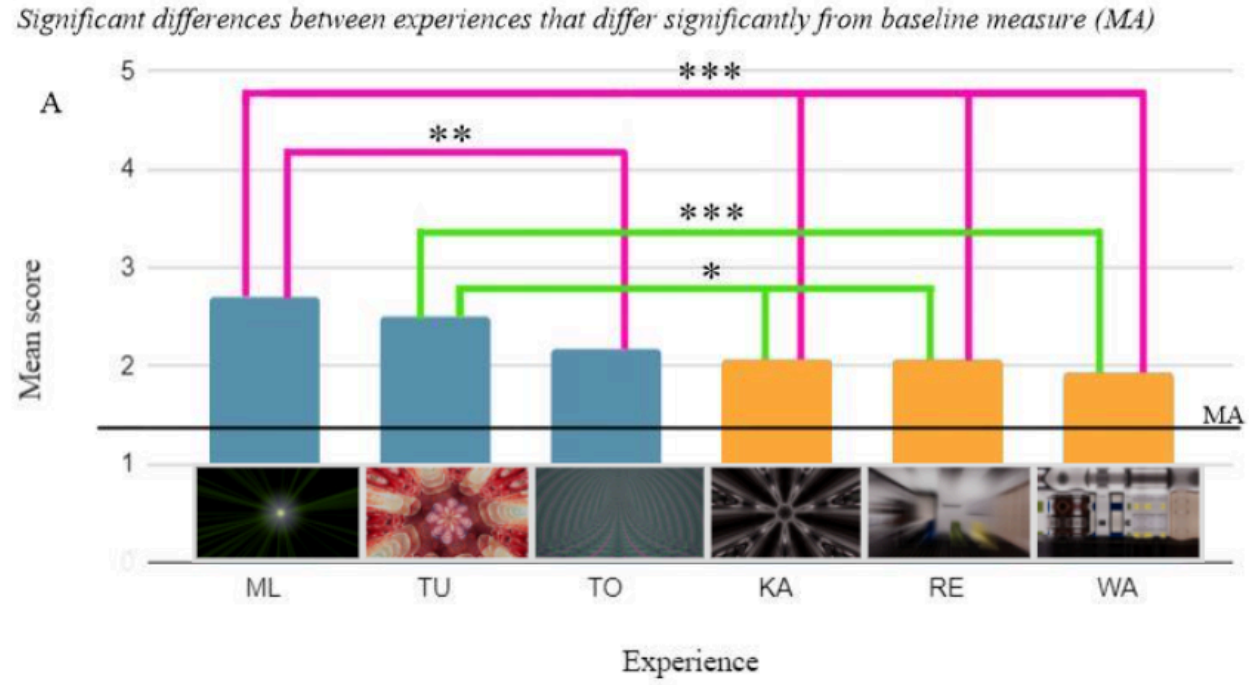
ANOVA

A repeated measures ANOVA was conducted to investigate the impact of psychedelic virtual and augmented reality on perceived psychedelic effects, as measured by a custom questionnaire (Figure 2, section A). The main effect of the experiences was found to be significant ($F=22.279$, $p<.001$), with a large effect size (partial eta squared = 0.669) indicating that 66.9% of the variance in the scores of psychedelic effect can be attributed to the differences among the experiences. A large F-value also confirms that substantial differences among the group means are likely not attributable to random chance but indicative of a systematic effect related to the experiences.

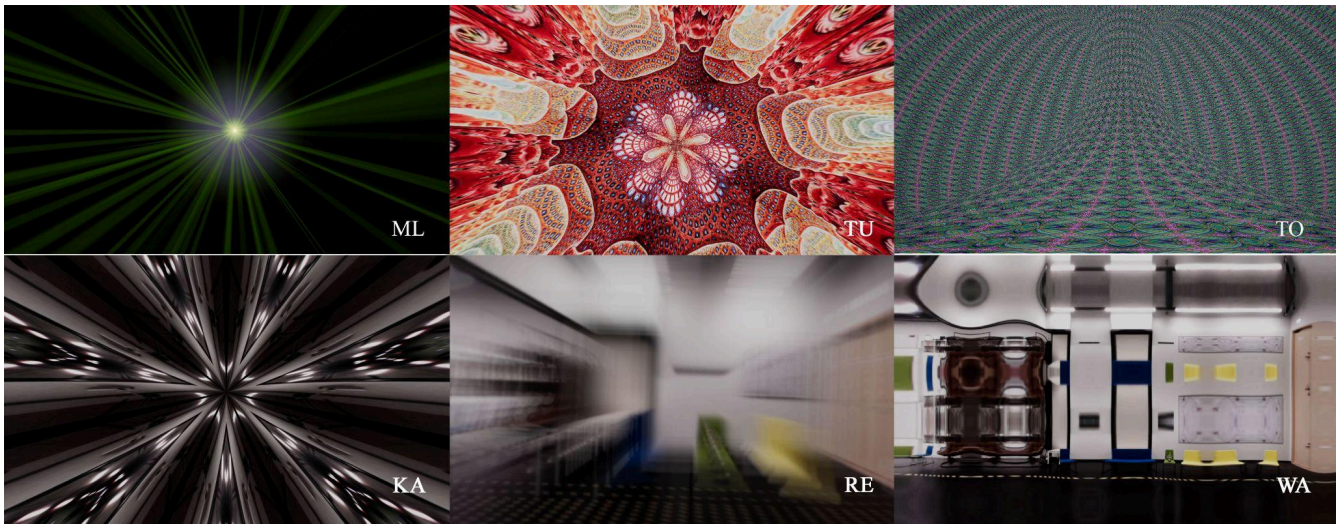
Mauchly's test of sphericity indicated a violation of the assumption of sphericity ($W=2.635e-9$; $p<.001$), leading to the application of the Greenhouse-Geisser correction. Subsequent Bonferroni and Holm post-hoc tests revealed that the Baseline measure (MA) differed significantly (according to Bonferroni test) from all three VR experiences ($p<.001$) and three highest scoring AR (KA $p<.001$; RE $p<.001$; WA $p<.01$) experiences. Further analysis was conducted exclusively on experiences that demonstrated statistical differences from the baseline measure (higher-scoring experiences).

The VR experience (see appendix A) with the highest score was ML, achieving a mean score of 2.712. ML showed significant differences from all experiences except TU as can be seen in Figure 2 section A. TU (Figure 2, section B) differed significantly only from AR experiences. The lowest scoring VR experience TO did not differ significantly from TU or any of the higher scoring AR experiences. The higher scoring AR experiences did not differ significantly from each other or from TO.

Figure 2



B



Note. The table (A) presents mean scores across all participants along with the statistical significance of differences. It includes only those experiences that showed significant differences from the baseline measure (MA). The pink lines indicate experiences significantly different from ML, while the green lines indicate differences from the TU experience (see appendix A). The

black line presents the score of the baseline placebo measure for comparison. Statistical significance was determined using the Bonferroni test: ***<.001; **<.01; *<.05. TO, KA, RE and WA did not differ significantly from each other. The B panel in this figure illustrates higher scoring cyberdelic experiences in descending order. VR experiences are in the upper row, while AR experiences are in the bottom row.

SAM affective scale correlations

Spearman correlations were found to be statistically significant ($p<0.05$) between affective valence and arousal dimensions ($r=0.166$, $p=0.007$) as well as affective arousal and dominance dimensions ($r=0.137$, $p=0.026$). Correlations are small, but statistically significant. Correlation between SAM1 and or a detailed breakdown of the SAM affective dimensions for each experience, please refer to appendix A.

Overall psychedelic experience correlated significantly and negatively with all SAM affective dimensions ($p<0.05$). Correlation was weak with SAM arousal ($r= -0.149$; $p=0.016$) and dominance ($r= -0.263$; $p<0.001$) dimensions and medium with SAM valence ($r= -0.349$; $p<0.001$) dimension.

Common configurations

During the experiment the subject could manipulate some characteristics of experiences (mostly speed of motion or intensity - see appendix A). Every time the subject changed configurations of the experience, the computer recorded that change. Configurations that participants spent most time in varied across participants and experiences. For most experiences two most common configurations (X:Y - denoting the two variables the participants could interactively change during the experience) were found. The only experience that had only one

common configuration was TU (see appendix A). Because the experience was intense - the common configuration (2:2) was close to the starting point (0:0) meaning that the tunnel moved slowly. Configurations for some experiences varied more than others and the subjects who inlaid the most extreme values were different for separate experiences. Note that differences between most common and other experiences are not tested to be statistically significant. Most common configuration for each experience is brought out in appendix A

Questionnaire assessment

To view the ranking of questions across higher-scoring experiences, please see Appendix B. This chapter assesses the overall quality of the questionnaire.

Reliability

Questionnaire reliability test was statistically significant ($p<.001$) Cronbach $\alpha = 0.895$. There were four questions that had weak item-rest correlation (<.5). These questions were SU (r=351), UU (r=0.393), HIL (r=0.486) and RA=(0.493) (see appendix B). These questions were critically assessed. After that UU and HIL were excluded from the analyses because they did not measure psychedelic effects. UU assessed the overall likeableness of the experience and HIL measured whether the experience continued after VR or not. When both questions were removed α was 0.897.

Comment-Question Correlation

Comment-question correlation analysis was statistically significant ($p<.001$) and showed Pearson's r= .689. This correlation was medium strength, close to strong (r>0.7).

Principal components analysis

UU and HIL questions (see appendix B) were removed before running the analysis. Principal component analysis was chosen over exploratory factor analysis because then raw non-parametric data can be used. Principal Component Analysis (PCA) with parallel analysis based on principal components ($p<.001$) detected one component with orthogonal and oblique rotation methods based on covariance as well as based on correlation. Utilizing the varimax rotation method in parallel analysis based on principal components decomposed on covariance matrix the uniqueness of questions varied from 0.276 (IG) to 0.799 (SU), with RA (0.702) and SU (0.799) having high uniqueness values above 0.7. Number of components based on eigenvalues also supported this model ($p<.001$) also with orthogonal and oblique rotation methods. Using covariance matrix and promax rotation method uniqueness ranged from 0.276 (IG) to 0.799 (SU). Eigenvalue for the component (PC1) was 5.539.

Discussion

The main objective of this study was to explore Virtual and Augmented Reality experiences, measure their psychedelic and compare the magnitude of these effects to each other. That allows to understand what cyberdelic experiences inflict a stronger result in overall psychedelic experience. That in turn enables to filter out stronger experiences for prospective research. To understand cyberdelic experiences even further SAM affective dimensions were also measured to explore their correlation with overall psychedelic effect.

Results of repeated measures ANOVA revealed that three VR experiences and three AR experiences differ significantly from baseline measure MA (see appendix A). VR experiences scored generally higher. Two out of three VR experiences differed significantly from all of the AR experiences indicating that VR is generally more psychedelic than AR. A common characteristic of all the AR experiences that significantly differed from the baseline measure is the possibility to make the world abstract. A correlation analysis disclosed that all SAM affective dimensions correlated significantly with overall psychedelic effect.

ANOVA results indicated that substantial differences in overall psychedelic effect are likely not attributable to random chance but indicative of a systematic effect related to the experiences. The baseline measure MA and lowest scoring AR experience TR (see appendix A) obtained lowest scores based on the mean score from the questions measuring psychedelic effect with TR having a bit bigger standard deviation. Six highest-scoring experiences (according to mean and sum of scores) differed significantly from the baseline measure. This suggests that visualizing psychedelic effects with virtual and augmented reality leads to a more pronounced psychedelic experience compared to using augmented reality without any effects - the placebo.

Essentially it means that to some extent psychedelic effects can be produced with cyberdelic technologies, both VR and AR.

A common characteristic of all the AR experiences that significantly differed from the baseline measure (RE, KA, WA - see appendix A) is the ability for subjects to multiply their vision to the extent that the picture becomes abstract. This aspect was not present in other AR experiences that scored lower and did not differ significantly from baseline measure. This observation suggests that an effective psychedelic AR experience involves the possibility of abstraction of the real world. On the other hand, common configurations revealed that, for many participants, high levels of abstraction was not necessary to reach a higher score of perceived psychedelic effect (see appendix A). Overall, the results on common configurations revealed that participants largely fell into two camps - those who liked mild experiences, and those who went for the extremes. In further experiences it might thus be sufficient to have just two different configurations available to participants in the experience or give participants more time to explore their preferred configurations.

Affective dimensions (SAM) of experiences were also measured to characterize the effects of cyberdelic experiences. All SAM affective dimensions (see appendix B) showed significant and negative correlations with overall psychedelic experience. Arousal and dominance showed weak, but significant correlation meaning that experiences making participants feel more in control tended to make them feel calmer. Both of these dimensions also correlated significantly and negatively with overall psychedelic effect. Characterizing stronger psychedelic effects to make subjects feel more excited, but less in control of the experience. From SAM results valence correlated weakly only with arousal dimension, exhibiting that if experience made subjects more excited it made them happier. Out of others it had the strongest

negative correlation with overall psychedelic effect meaning that stronger cyberdelic experiences made subjects feel more happy. That finding supports the idea that cyberdelic technologies could have therapeutic effects (Kaup, et al. 2023) similar to psychedelic drugs (Majic, et al. 2015).

Questionnaire assessment shows that, after adjustments, according to the unidimensional reliability of the questionnaire ($\alpha = 0.897$), the test of perceived psychedelic effect is suitable for use in research ($\alpha > 0.8$). Rather high reliability means putting together questions about all the psychedelic dimensions mentioned before created an overall factor that can be considered coherent. Principal Component analysis supports the suggestion of high reliability. Showing a statistically significant model ($p<.001$) of one component with each rotation method with parallel analysis based on principal components and analysis based on eigenvalues applied to it. The last thing to evaluate the validity of the questionnaire was finding correlation between comments and questionnaire responses. The correlation ($r=.689$; $p<.001$) was statistically significant and medium strength, close to strong. There could be various reasons for this finding. Firstly, comments that didn't explicitly mention specific psychedelic aspects were assigned 0 points. However, the absence of such mentions in the comments does not necessarily imply that the subjects did not experience those aspects. Secondly, there was a phenomenon where subjects who mentioned psychedelic aspects in their comments did not consistently report them in the questionnaire. For example, in the MA experience (see appendix A), a subject commented on a surreal dreamy room after death but gave only two points to the SU question of thinking about death (see appendix B). This phenomenon was observed, particularly in questions related to SU and TA (see appendix B). It suggests that subjects might have experienced more psychedelic aspects than they reported, possibly due to a loss of meaning during the interpretation of the

questions. To address this, extending the questionnaire length with multiple questions for each aspect could be beneficial, also rephrasing more problematic questions in that area.

Previous studies in this area have explored the effects of psychedelic virtual reality. As mentioned above Kaup et al (2023) explored the therapeutic use against depression and anxiety symptoms. They did not measure experiences separately, but an overall effect of cyberdelic virtual reality. All the Virtual Reality experiences used in the current study were also in the aforementioned study done by them. Selecting already tested VR experiences might be the reason why VR experiences scored higher than AR experiences. Other researchers have studied VR simulated psychedelic hallucinations' effect on cognitive flexibility (Rastelli et al. 2022). According to them ,VR simulated visual hallucinations enhance cognitive flexibility, which could also mean potential therapeutic effects. Although psychedelics and their working mechanisms have been studied rather widely there is a lack of cyberdelic studies. Especially exploring the effect AR simulated visual psychedelic hallucinations and comparing different cyberdelic effects with each other. That is what makes current study so unique.

There were some limitations to this study. As mentioned, VR experiences used in current research had been previously used in a study by Kaup et al (2023). Choosing tested VR experiences might be one of the reasons VR experiences scored higher. None of the AR experiences in current research had been experimentally tested before. Another reason for VR scoring higher might be a higher proportion of AR experiences leading to habituation effect towards psychedelic AR. . Baseline measure was also an AR experience, leading other AR experiences to have more similar effects. To some extent, many AR experiences were similar, because the whole experiment was performed in a lab offering unstimulating and stoic surroundings compared to a more natural and dynamic environment. On another note, subjects

got to see each experience only for three minutes, which may be too short for psychedelic effects to emerge. The study consisted of numerous experiences to test leading to short duration for each one individually. As psychedelic AR was never tested before it was difficult to predict which experiences had stronger effects. So including more AR experiences allowed a more comprehensive understanding of what works, and what does not. In the future, experiences with stronger psychedelic effect can be picked out allowing subjects to experience them for a longer period of time. The questionnaire itself was short and included only one question for each aspect of psychedelic experience. Including fewer experiences allows to extend the questionnaire which in turn could give more accurate results about the aspects of psychedelic experience to emerge. Some of the questions in the questionnaire were also poorly phrased leading to some level of contradiction between questions and comments.

Regardless of the limitations of this study it was an important step in cyberdelic science because it is one of the first (if not the first) studies that incorporate psychedelic AR experiences. Also the first to compare different psychedelic VR and AR experiences with each other according to perceived psychedelic effect they produced leading to better understandings of what kind of cyberdelic experiences have a more pronounced psychedelic effect to be used in future research. That sets the discourse of psychedelic research to test out and use cyberdelics more as a safer and more accessible alternative to psychedelic drugs.

As cyberdelic research is a new branch in psychedelic studies there is much more to explore. In current study, subjects had only three minutes for each experience. In the future different durations of the experience should be compared to find out which duration is optimal for psychedelic effect to emerge. It might vary across different experiences in VR and AR. After finding the optimal duration weaker scoring experiences should be tested again to find out

whether more optimal duration brings out their effects. Different aspects of cyberdelic experience should also be researched through previously made and reliable questionnaires such as ASC (Dittrich, 1998; Studerus et al., 2010), PCQ (Brouwer, Carhart-Harris, 2021), APEQ (Wolff et al., 2022), EDI (Nour et al 2016) and MEQ (MacLean et al 2012). Also, a comprehensive study should be made for creating a questionnaire testing an overall psychedelic effect combining all the aspects that create psychedelia. In the future cyberdelics should also be combined with auditory experience to find out optimal auditory counterpart to simulated visual hallucinations possibly leading to bigger effect size. It is possible that different experiences require different auditory stimulation. Going further, AR experiences should be tested more as they showed potential in creating psychedelic effects and can be applicable to more active experiments than VR since subjects see their surroundings. As technology continues to advance, augmented reality (AR) should be explored in more immersive and stimulating environments, allowing subjects to interact with their surroundings. Psychedelic drugs (Pacheco, et al. 2023) and even cyberdelics are shown to enhance cognitive flexibility (Rastelli et al 2022) so more research should be done on it to explore that function, for example creative performance and flow state. Last but not least, cyberdelics should be tested with microdosing real psychedelic drugs to find out the extent to which they interact. Taking into account that they produce similar effects allows to deduce that they might amplify the effect of each other. Cyberdelics are highly manageable stimuli meaning that they could be used to manipulate and control the effect of psychedelic drugs leading to more targeted results.

Conclusion

This study assessed the differences in psychedelic effects on 11 psychedelic virtual (VR) and augmented (AR) reality experiences as well as one AR baseline measure. Six psychedelic experiences differed significantly from the baseline measure MA, encompassing three VR and three AR reality experiences. VR experiences generally scored higher in psychedelic effect, with the two top-scoring virtual reality experiences, ML and TU, differing significantly from all AR experiences. Among the higher-scoring AR experiences, no significant differences were found, and they did not differ significantly from the lowest-scoring VR experience. SAM affective scale dimensions showed weak correlations with the overall psychedelic effect. The custom-made questionnaire demonstrated good reliability, and Principal Component Analysis revealed a single component supporting the high reliability of the questionnaire.

In conclusion, this study showed that in comparison with the baseline measure three psychedelic VR and three AR experiences produced higher perceived psychedelic effects, with VR experiences scoring higher. In general, these results imply that cyberdelics can create an effect similar to psychedelic drugs. The present study was one of the first studies to compare cyberdelic experiences with each other and incorporate AR experiences into research. The results of this study can be used to further investigate the phenomena of digital psychedelics.

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Appendix A. Descriptions of experiences

The study encompassed a total of 12 experiences made by Madis Vasser and Karl Kristjan Kaup. These experiences include one baseline measure (MA), three Virtual Reality experiences also utilized by Kaup et al. (2023), and eight Augmented Reality experiences unique to this study. Experiences were assessed by custom-made questionnaire on a 5-point scale (See appendix B) including Self Assessment Manikin (SAM) scale and questions to measure overall perceived psychedelic effect (see appendix B). Among the 11 psychedelic experiences, six exhibited significant differences from the baseline measure MA according to overall perceived psychedelic effect. While mixed measures ANOVA and Bonferroni post-hoc tests were applied to all experiences, a more in-depth analysis focused specifically on those differing significantly from the baseline measure.

Differences in SAM dimensions (see appendix B) for individual experiences are not tested with ANOVA due to the high volume of this study. Correlation analysis showed medium correlation in which experiences that made subjects happier also made them experience higher overall psychedelic effect. A small, but significant correlation shows that experiences scoring high in SAM dominance arousal dimensions tended to score low in overall psychedelic effect. Overall psychedelic experience correlated weakly with all SAM dimensions.

Mystical Light (ML) - Virtual Reality

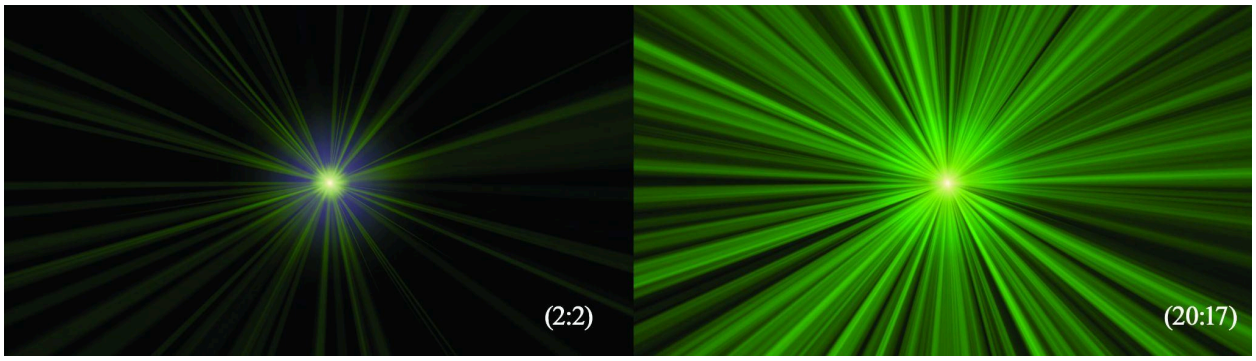
The experience took place in a completely dark room with a single ball of light in the center of the field of vision when looking straight ahead. Using one controller, participants could manipulate the number of rays emanating from the light, while the other controller allowed them to enlarge the halo of the light ball and alter the interval tempo of changing colors. Two most common configurations for this experience were (2:2) and (20:17) (see figure 3, section B).

Notably, participants scored this experience quite highly in the happiness dimension (see figure 3, section A), indicating a significant elevation in happiness levels. However, it received a notably lower score in the control dimension, suggesting that participants felt the experience was controlling them rather than the other way around. The relatively low sense of control may be attributed to the slight delay in the responsiveness of the controls. This experience received the highest overall score among all, with a (mean= 2.712; SD=1.52) in psychedelic effect. It differed significantly from all other experiences, except TU.

Figure 3

A) Mystical Light (ML) in SAM dimensions

B) Common configurations of ML experience.



Note. Section A shows how subjects rated ML effect on a 5-point SAM scale. Lower part, section B shows snippets from common configurations of this experience.

Tunnel (TU) - Virtual Reality

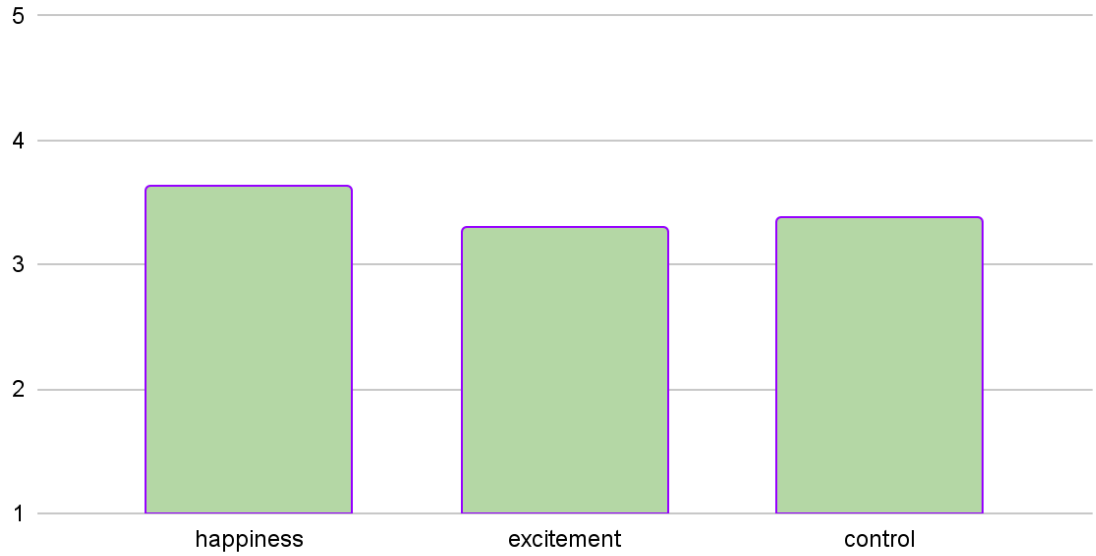
The painting "Net of Being" (Grey, 2007) was transformed into an endless tunnel in virtual reality (see figure 4, section B). Using one controller, participants could make the tunnel move forwards and backwards and regulate the speed. With the other controller, they could make the tunnel spin in both directions and control the speed of the spinning tunnel.

It's noted that this experience had only one common configuration (2:2). Participants did not spend much time in higher configurations. Several participants mentioned in the comments that the experience made them feel dizzy, which could explain why many people did not choose to spend time in higher configurations, where the tunnel would move faster.

This experience received balanced scores across all SAM affective dimensions (see figure 4, section A).This experience ranked as the second-highest in terms of psychedelic effects, receiving a (mean= 2.507; SD =1.5). It exhibited significant differences from all AR experiences, but not with other VR experiences.

Figure 4

A) Tunnel (TU) in SAM dimensions



B) Illustration of TU experience.

Note: Section A of this figure depicts how subjects rated the TU effect on a 5-point SAM scale. Section B presents a picture of the experience. Common configurations are not illustrated for this

experience, as the subject could manipulate only the speed and direction of movement, which doesn't show on a static picture.

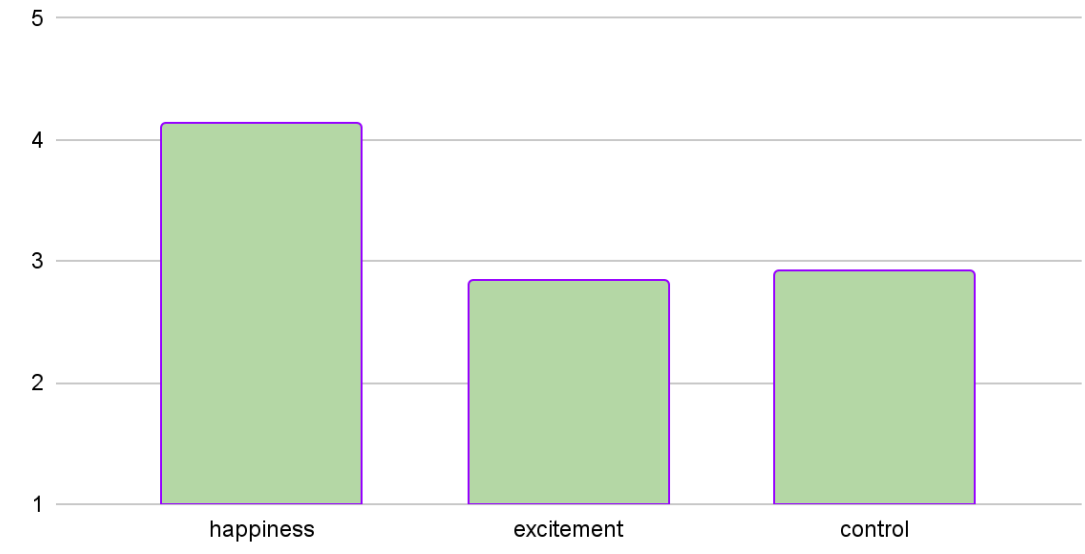
Torus (TO) - Virtual Reality

Participants were immersed inside a giant 3D donut, facing towards the center, with brightly colored walls. (see figure 5) Using controllers, they could manipulate the movement of the walls—one controller for spinning left and right, and the other for spinning up and down. Common configurations for this experience were (3:3) and (5:30) (see Figure 5, section B).

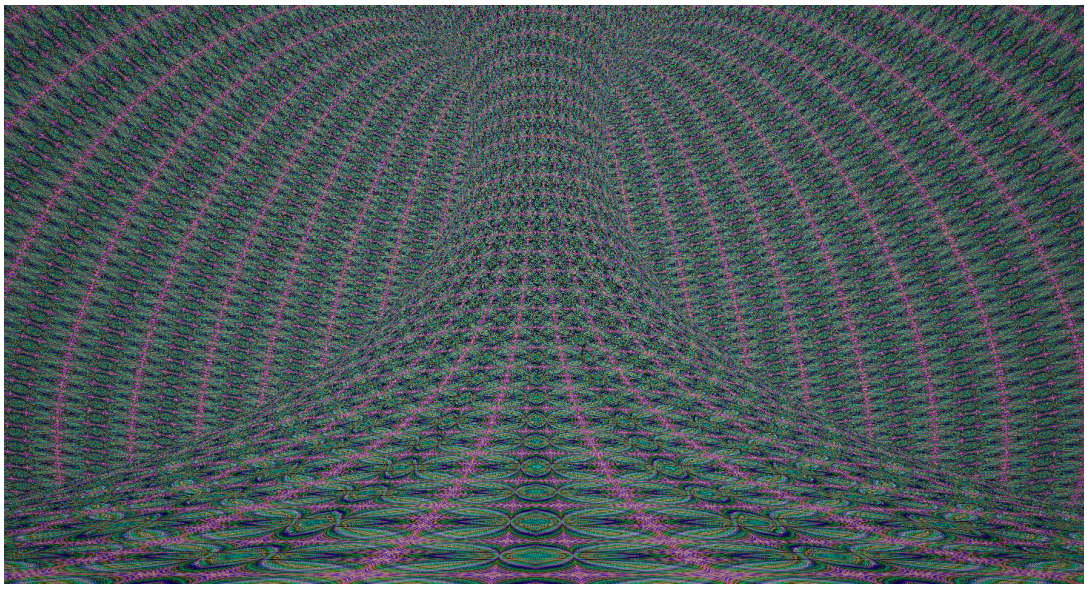
In SAM affective dimensions, it received relatively high scores in happiness (see figure 5, section A). However, concerning psychedelic effects, it scored the lowest among VR experiences (mean= 2.194; SD= 1.401) and was the only one that did not differ significantly from the three highest-scoring AR experiences. It also did not differ significantly from TU experience. Nonetheless, it did differ significantly from the baseline measure MA.

Figure 5

A) Torus (TO) in SAM dimensions



B) Illustration of TU experience.



Note. Section A of this figure shows how subjects rated TO effect on a 5-point SAM scale. Section B shows a picture of the experience. Subjects could only manipulate the speed and direction of the movement snippets from common configurations of this experience thus common configurations can't be shown on a static picture.

Kaleidoscope (KA) - Augmented Reality

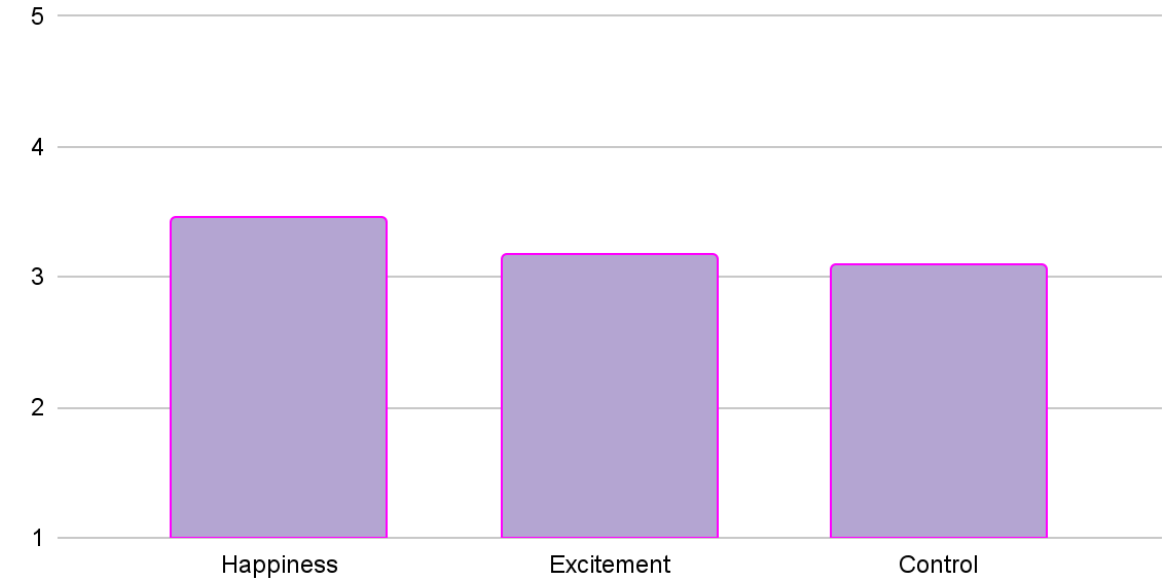
In this particular experience, the image displayed on the VR headset screen was divided into sectors. The central point remained fixed regardless of head position. Within these sectors, the picture moved kaleidoscopically in response to the subject's head movements. One controller facilitated left and right movement of the central point, while the other allowed the addition or removal of sectors. Most common configurations are (2:2) and (18:10) (see figure 6, section B).

This experience ranked among the three highest-scoring AR experiences, and did not exhibit significant differences from the other two in terms of psychedelic effects. It also did not

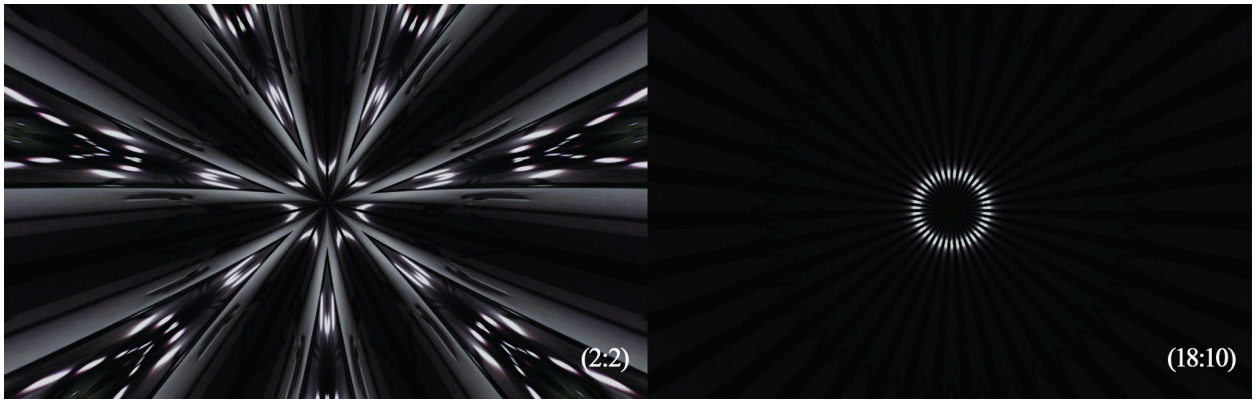
exhibit significal differences from the lowest scoring VR experience TO. SAM scores (see figure 6, section A) remained relatively stable across all three dimensions for this set of experiences.

Figure 6

A) Kaleidosope (KA) in SAM dimensions



B) Common configurations of KA experience.



Note. Upper part, section A of this figure shows how subjects rated the KA effect on a 5-point SAM scale. Lower part, section B shows snippets from common configurations of this experience.

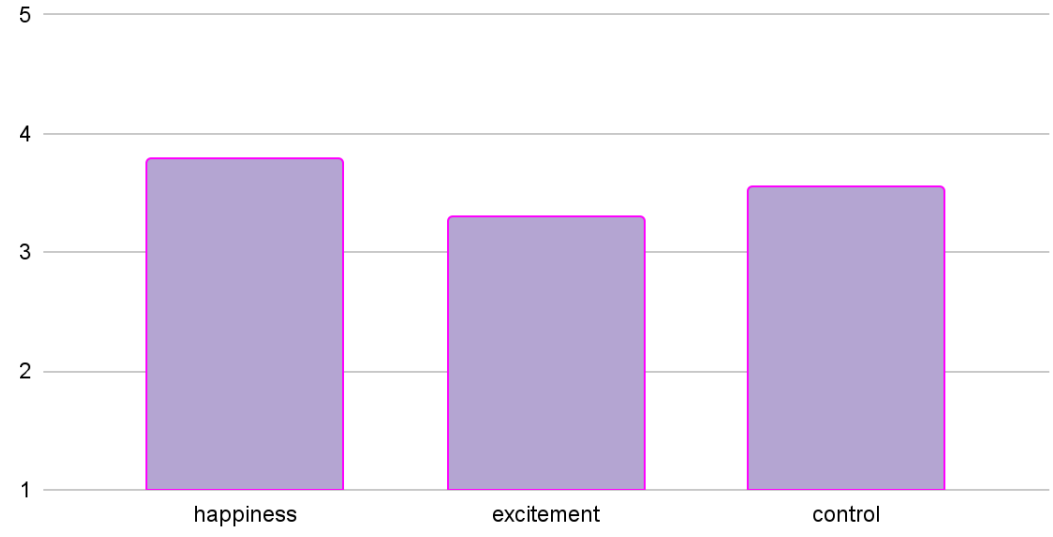
Recursion (RE) - Augmented Reality

This effect multiplies the image imitating the recursion effect seen in nature, computer sciences, math, music, language and visual arts (LMU, n.d.). It is created by repeating specific sections of camera picture across itself in a self-similar fashion. With one controller the subject can multiply the picture until it turns abstract. Other one controls the brightness of the picture. The most common configurations were (3:7) and (23:34) (see figure 4, section B).

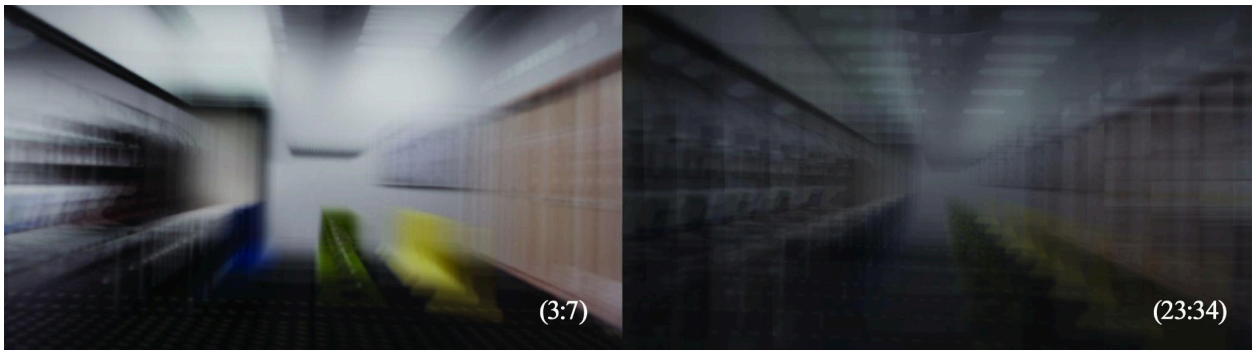
This experience was among the three highest-scoring AR experiences (mean= 2.052, SD =1.224), and notably, it did not differ significantly from the other two in terms of psychedelic effects. It also didn't differ significantly from the lowest scoring VR experience TO. It did differ from the two highest-scoring VR experiences, ML and TU. On SAM dimensions it scored a bit higher in happiness compared to other dimensions (see Figure 4, section A).

Figure 7

A) Recursion (RE) in SAM dimensions



B) Common configurations of RE experience.



Note. Section A chart shows how subjects rated RE effect on a 5-point SAM scale. Section B of the figure shows the most common configurations of RE experience.

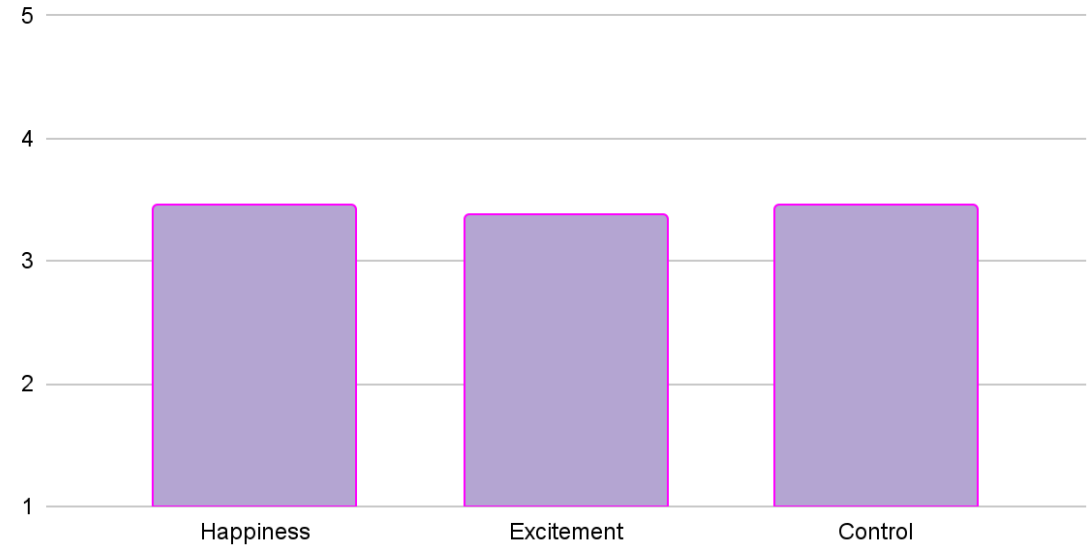
Waving (WA) - Augmented Reality

This effect induces a visual stretch in both horizontal and vertical directions, creating a waving motion. One controller governs the speed, while the other controls the amplitude. Once the amplitude reaches a threshold, the image multiplies, generating multiple rooms that wave in synchronization. The most common configurations (3:3) and (14:7) exhibited modest variation (see Figure 8, section B).

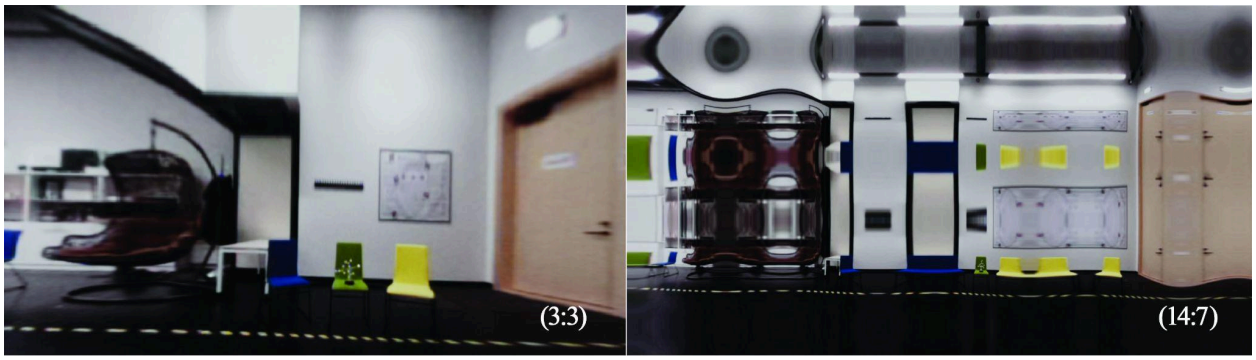
This experience ranked among the three highest-scoring AR experiences (mean= 1.941; SD = 1.255) and did not show significant differences from the other two AR experiences and the lowest scoring VR experience TO in terms of psychedelic effects. The SAM scores, as outlined in Figure 8, section A, remained stable across all three dimensions for this group of experiences.

Figure 8

A) Waving (WA) in SAM dimensions



B) Common configurations of WA experience.



Note. Section A of the Figure shows how subjects rated WA effect on a 5-point SAM scale. Lower part, section B, shows the most common configurations of this experience.

Particles Global (PG) - Virtual Reality

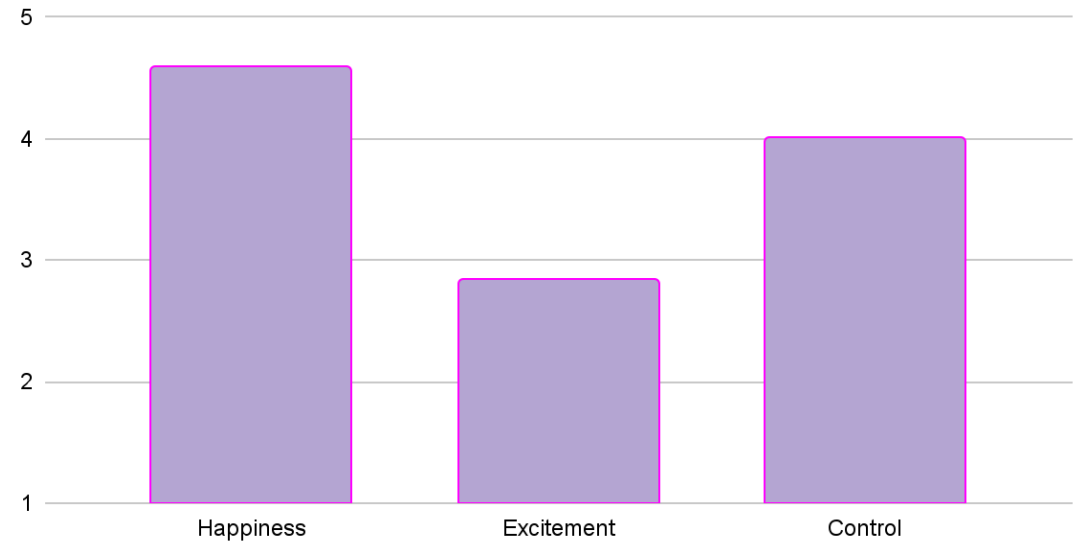
In this experience, the participant viewed the lab through cameras, observing numerous particles that defied gravity and changed colors within the RGB scale. One controller permitted the adjustment of the speed at which particles moved and how rapidly they changed colors. The

other controller enhanced the subject's control over the particles through hand movements making the particles gravitating towards or away from hands. The most common configurations (3:4) and (51:44) (see Figure 9, section B) displayed the highest variation among all the experiences, with only a few instances of high configurations chosen by subjects for an extended duration.

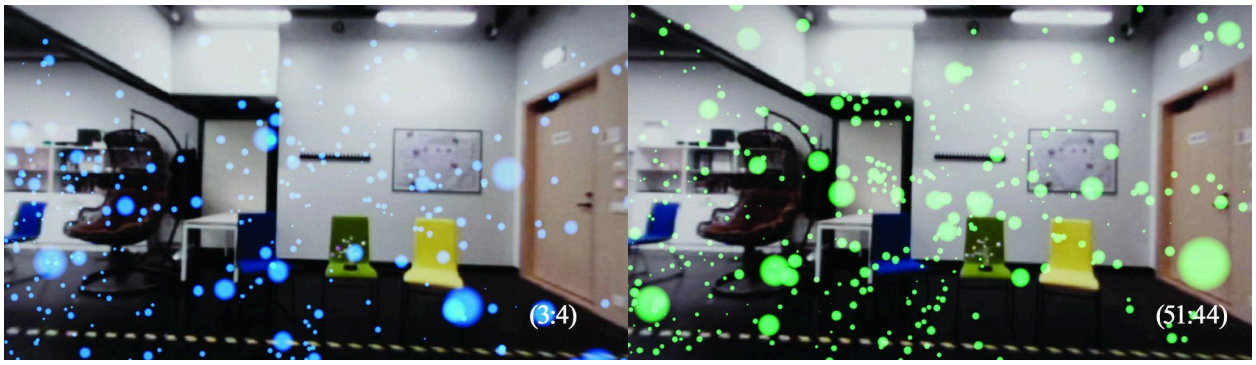
Despite being enjoyable for participants (see Figure 9, section A), this experience did not yield high scores in terms of psychedelia (mean= 1.767; SD= 1.209). It garnered high ratings in the SAM affective scale's happiness and control dimension, making it the most positive experience overall. However, psychedelic effect didn't exhibit significant differences from the baseline measure MA.This experience received the highest number of comments expressing positive affect, with a few participants even suggesting the idea of transforming it into a VR game. However, despite the positive affect, subjects provided it with a low rating in terms of excitement.

Figure 9

A) Particles Global (PG) in SAM dimensions



B) Common configurations of PG experience.



Note. The chart in section A shows how subjects rated PG effect on a 5-point SAM scale. The B section of the Figure shows two most common configurations of that experience.

Chromatic (CH) - Augmented Reality

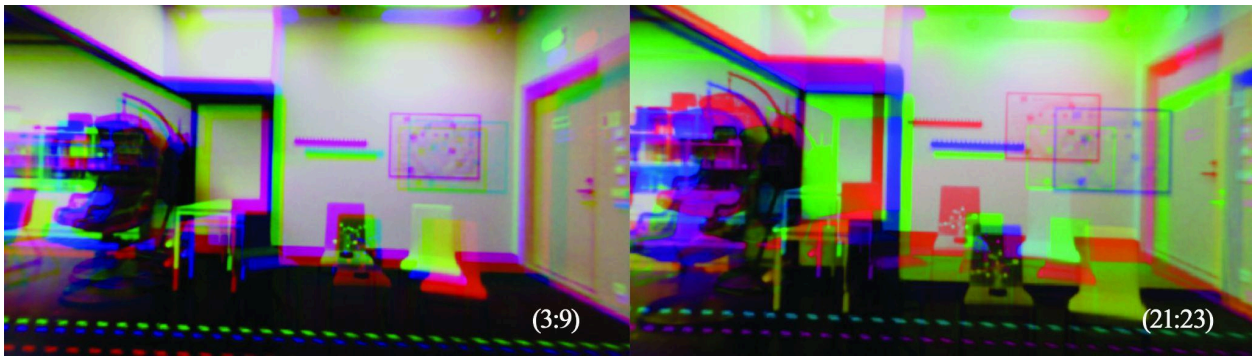
This effect simulates RGB chromatic aberration by layering the edges and distorting the colors, producing a vivid representation of the real world. Chromatic aberration occurs due to variations in the indices of refraction with wavelength. It results from the inability to focus multiple wavelengths onto the same focal plane, as different wavelengths travel at different speeds. Consequently, different colors can deviate from a focal plane, producing the chromatic aberration effect. One controller adjusted the speed of the colors in motion, while the other controlled the amplitude between pictures. The most common configurations (see Figure 10, section B) for this experience, (3:9) and (21:23), showed relatively small variation. However, this experience had two outliers who chose extremely high levels of this experience.

It achieved relatively high scores in the SAM happiness dimension (see the Figure 10, section A) compared to other experiences that did not differ significantly from baseline measure MA according to overall psychedelic effect (mean= 1.632, SD= 1.014).

Figure 10

A) Chomatic (CH) in SAM dimensions

B) Common configurations of CH experience.



Note. Section A, the chart, shows how subjects rated CH effect on a 5-point SAM scale. Pictures in section B illustrate the two most common configurations of this experience.

Alcohol (AL) - Augmented Reality

In this experience, participants observed a live camera image of the lab with partly transparent layers moving towards and away from each other. This simulation aimed to replicate the effect commonly experienced under the influence of alcohol. One hand of the participant

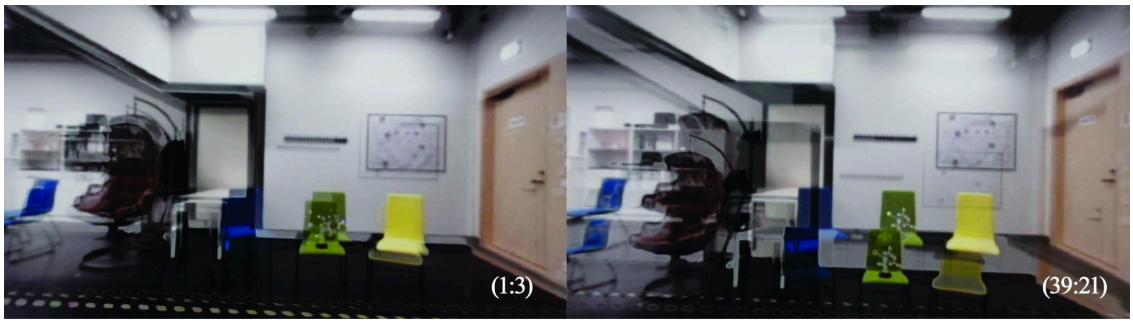
controlled the speed, while the other managed the amplitude of the movement. The prevalent configurations (see Figure 11, section B) for this particular experience were (1:3) and (39:21), showcasing significant variation within this range.

According to psychedelic effects (mean= 1.667), it did not differ significantly from the baseline measure MA. In SAM dimensions (see figure 11, section A), it scored high in control and happiness dimensions but low in excitement.

Figure 11

A) Alcohol (AL) in SAM dimensions

B) Common configurations of AL experience.



Note. The section A of the figure shows how subjects rated the AL effect on a 5-point SAM scale. Section B illustrates the most common configurations of the experience.

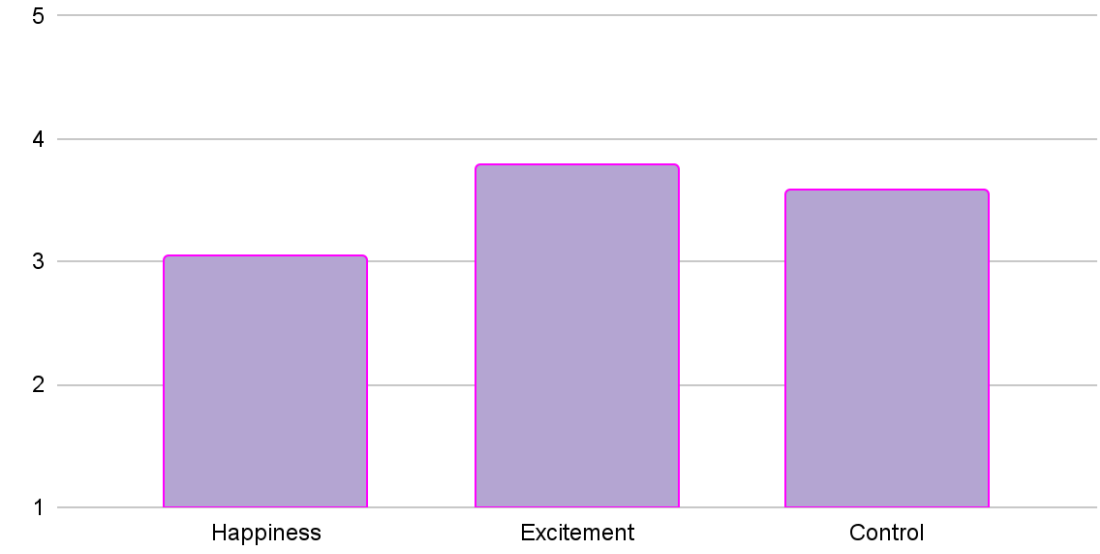
Breathing (BR) - Augmented Reality

This effect was created using a live camera image from the headset, simulating the movement of water when droplets fall into it. The controller allowed the user to change the interval. Other one wasn't functional. The most frequent configurations (see Figure 12, section B) for this effect were (4:9) and (19:18), with the majority of configurations clustering towards the lower end of the range.

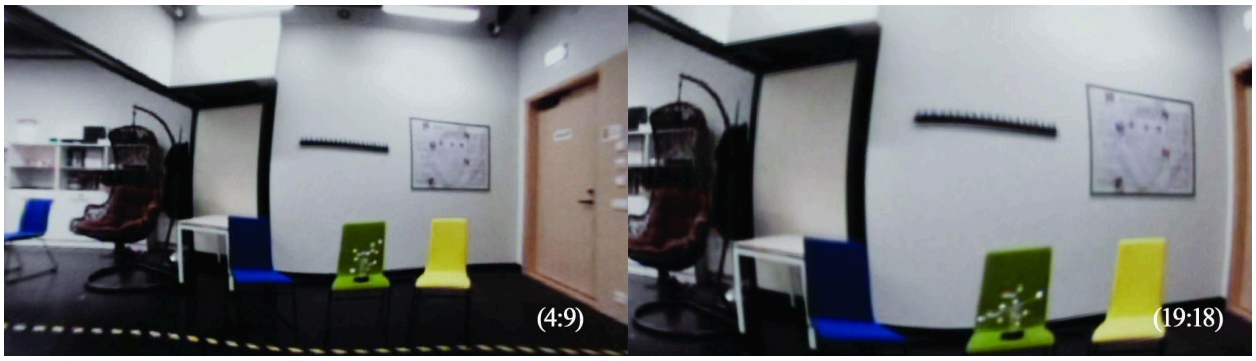
According to psychedelic effects, this experience did not differ significantly from the baseline measure. On the SAM scale (see figure 12, section A), participants scored this experience relatively low in the happiness dimension.

Figure 12

A) Breathing (BR) in SAM dimensions



B) Common configurations of AL experience.



Note. Section A shows how subjects rated BR effect on a 5-point SAM scale. Lower part, section B, illustrates two most common configurations of the experience.

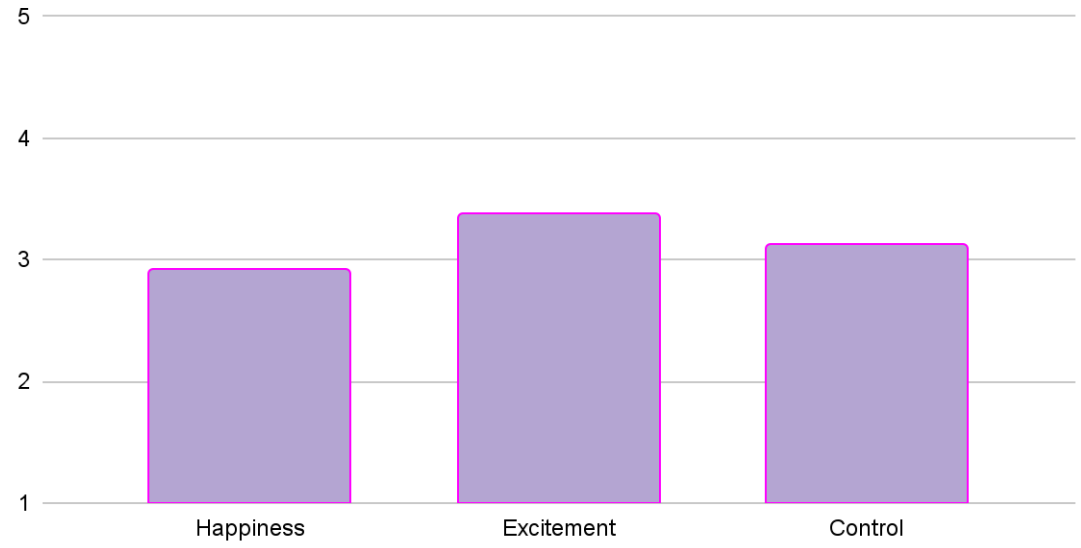
Tracers (TR) - Augmented Reality

This effect replicates the visual tracers hallucinations described in a psychedelic study. When an object in the participant's visual field is in motion, it leaves behind an afterimage that fades slowly. One controller regulates the speed at which the afterimage fades. Most common configurations (see Figure 13, section B) were (1:2) and (14:14) rather close to the baseline

Interestingly, this question had the same mean score in psychedelic effect as the baseline measure (Mean=1.397). It received a similar score across all SAM dimensions (see figure 13, section A).

Figure 13

A) Tracers (TR) in SAM dimensions



B) Common configurations of BR experience.

Note. Upper section, A, shows how subjects rated TR effect on a 5-point SAM scale. Section B illustrates common configurations of TR experience, when the subject wasn't moving.

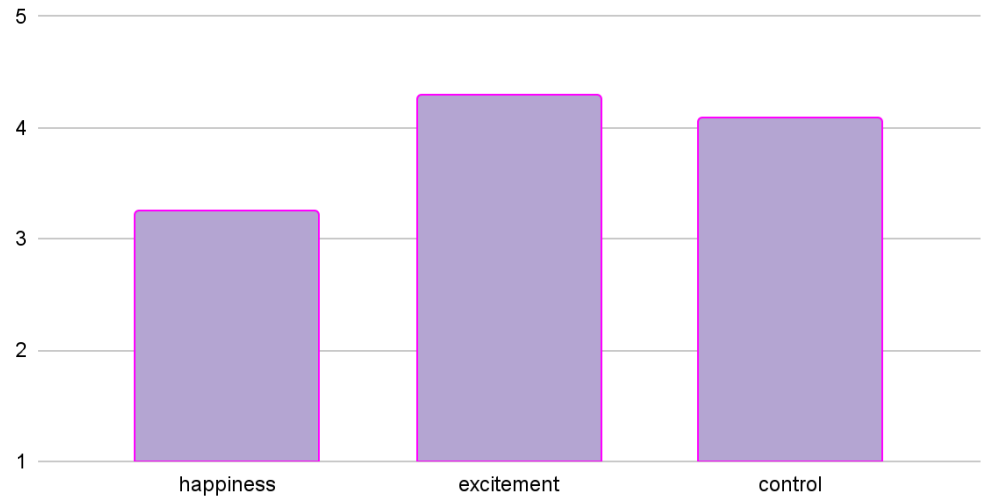
Baseline measurement/ Placebo condition - Main (MA) - Virtual Reality

It was the first experience every subject saw. During this experience subjects saw the lab through the camera of the headset (see Figure 14, section B). This experience was not customizable and the controls did not work.

This experience scored high in the SAM excitement dimension (see Figure 14, section A), but it was highly likely because it was the first experience the subjects saw. It did not evoke happiness and several comments said they were disappointed with the experience. This experience allowed to lower participants' expectations.

Figure 14

A) Baseline measurement in SAM dimensions



B) Snippet from baseline experience MA

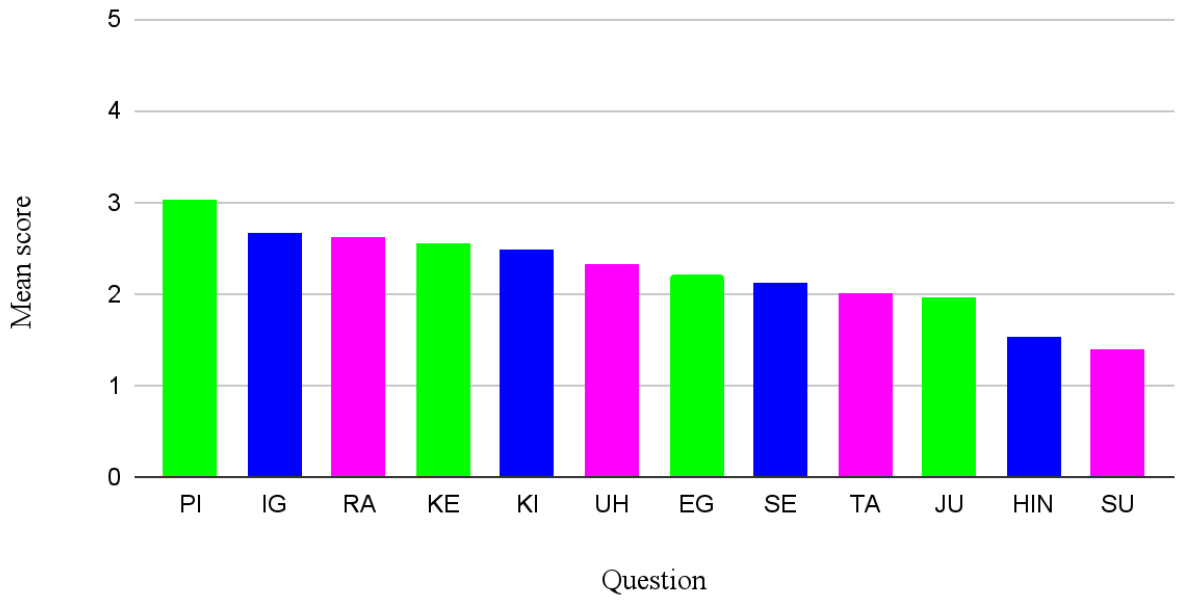
Note. Section B, the chart, shows how subjects rated MA effect on a 5-point SAM scale. The subject s couldn't change any parameters of the experience, thus there are no common configurations for this experience. Camera picture of the lab is shown in section B.

Appendix B. Commented questionnaire.

The questionnaire was originally in Estonian. For clarity, a commented version was created. This version includes the original questions, translated questions, and added comments. During the experiment, questions were presented in a randomized order. The experience code and comment questions remained constant throughout the entire experiment, code was first and comment question last. Responses to all questions were recorded on a 5-point scale. Figure 16 Illustrates the mean scores of subjects left to the questions across the six higher scoring experiences. Note that significance of the differences between those values have not been assessed due to the high volume of this study.

Figure 16

Mean scores of questions

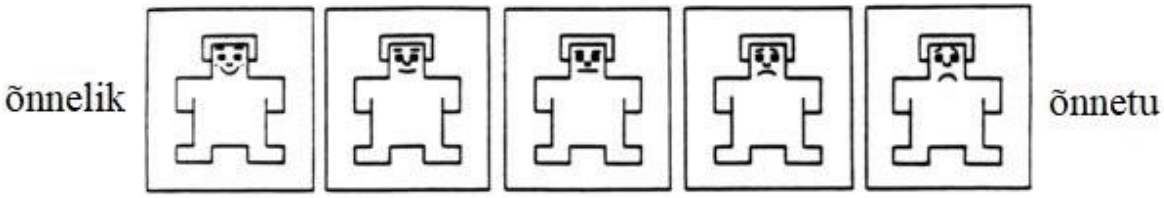


Note. This table shows averages of question scores (max 5) among experiences that scored higher than baseline measure MA (see appendix A). Whether differences are significant has not been assessed for this table.

1. **SAM1**. *Mis tundeid see kogemus Teis tekitas?*

What feelings did this experience evoke?

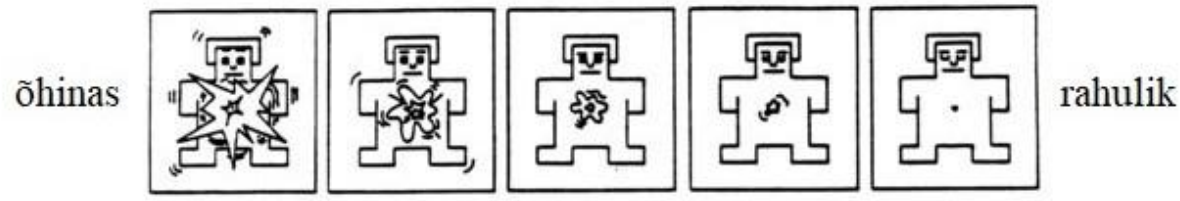
Happy Sad.



*Note.*This question measured SAM (Bradley & Lang, 1994) affective valence. In this appendix it was rotated as it was counterintuitive to interpret in comparison with the other SAM dimensions in appendix A. However, in the data analysis, an original, non-rotated version was used.

2. **SAM2**. *Mis tundeid see kogemus Teis tekitas?* What feelings did this experience evoke?

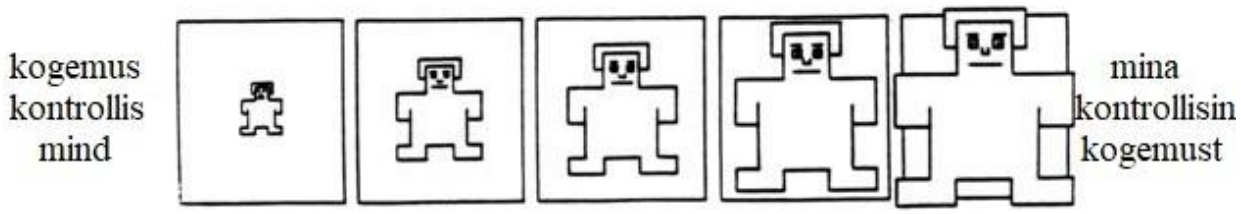
Excited Calm



Note. This question measured SAM (Bradley & Lang, 1994) arousal dimension. Whether the experience made participants feel excited or calm

3. **SAM3**. *Mis tundeid see kogemus Teis tekitas?* What feelings did this experience evoke?

Experience controlled me I controlled the experience



Note. This question measured the SAM (Bradley & Lang, 1994) dominance dimension. Whether participants felt like they're in control of the experience or other way around.

4. **KI**. *Tundsin, et kogemust ei saa sõnadega kirjeldada.*

   Mitte rohkem kui tavaliselt ○ ○ ○ ○ ○ ○ *Täielikult*

I felt like the experience can't be described with words.

Not more than usual○ ○ ○ ○ ○ ○ Completely

Note: This question measures Ineffability, indicating that experience cannot be encapsulated in words. This dimension of the psychedelic experience was adopted from the Mystical Experience Questionnaire (MEQ 30, MacLean et al., 2012; Barrett, Griffiths, 2018) and the Psychological Insight Questionnaire (PIQ, Davis et al., 2021).

5. **IG.** *Tundsin, et kogesin igavikku või lõpmatust.*

   Mitte rohkem kui tavaliselt ○ ○ ○ ○ ○ ○ *Täielikult.*

I feel like I experienced transcendence of time

Not more than usual○ ○ ○ ○ ○ ○ Completely

Note: This question is designed to measure the transcendence of time, showing the loss of conventional temporal perception. This aspect is also drawn from the Mystical Experience Questionnaire (MEQ30 - MacLean et al., 2012; Barrett, Griffiths, 2018), the Psychedelic Change

Questionnaire (PCQ-20 - Brouwer, Carhart-Harris, 2021), and the 11 Dimensions Altered States of Consciousness Questionnaire (11D-ASC - Dittrich, 1998; Studerus et al., 2010).

6. **PI.** *Tundsin, et asun piirideta ruumis.*

   Mitte rohkem kui tavaliselt ○ ○ ○ ○ ○ ○ *Täielikult*

I felt like I was in a limitless room.

Not more than usual○ ○ ○ ○ ○ ○ Completely

Note. This question measured Transcendence of space, implying the absence of conventional spatial perception. That is also used in Mystical Experience Questionnaire (MEQ30 - MacLean et al., 2012; Barrett, Griffiths, 2018) and Psychedelic Change Questionnaire (PCQ-20 - Brouwer, Carhart-Harris, 2021), 11 dimensions altered states of consciousness questionnaire (11D-ASC - Dittrich, 1998; Studerus et al., 2010)

7. **JU**. *Tundsin, et kogetu on püha*

   Mitte rohkem kui tavaliselt ○ ○ ○ ○ ○ ○ *Täielikult*

I felt like the experience was sacred

Not more than usual○ ○ ○ ○ ○ ○ Completely

Note: This question assessed sacredness, indicating a sense that what is encountered is holy or sacred, accompanied by a feeling of awe. This dimension is associated with potential benefits against depressive symptoms, offering a sense of hope (Majic, et al. 2023). It is measured in the Mystical Experience Questionnaire (MEQ30 - MacLean et al., 2012; Barrett, Griffiths, 2018), the 11 Dimensions Altered States of Consciousness Questionnaire (11D-ASC - Dittrich, 1998;

Studerus et al., 2010), and the Psychedelic Change Questionnaire (PCQ-26 - Brouwer, Carhart-Harris, 2021).

8. **UU**. *Nautisin kogemust ja tahaksin seda uuesti kogeda.*

   Mitte rohkem kui tavaliselt ○ ○ ○ ○ ○ ○ *Täielikult*

I enjoyed the experience and would like to experience it again

Not more than usual○ ○ ○ ○ ○ ○ Completely

Note: This question originally measured the likability of the experience and overall acceptance behavior towards this experience. Similar aspects, such as feelings of ecstasy and joy interpreted as positive mood, are addressed in the Mystical Experience Questionnaire (MEQ - MacLean et al., 2012; Barrett, Griffiths, 2018) and the Acceptance/Avoidance-Promoting Experiences Questionnaire (APEQ - Wolff et al., 2022). However, this question was later excluded from the analyses due to poor correlation with other questions and its tendency to measure overall user experience rather than specific psychedelic effects.

9. **HIN**. *Kogemus pani mind mõnd asja elus ümber hindama.*

   Mitte rohkem kui tavaliselt ○ ○ ○ ○ ○ ○ *Täielikult*

Experience made me reevaluate some things in life.

Not more than usual○ ○ ○ ○ ○ ○ Completely

Note: This question assessed the subjects' feeling of revelation, prompting them to explore the depths of fundamental truths and reassess certain aspects of their life. This dimension could potentially be linked to working mechanisms against anxiety and depressive symptoms (Majic, et al. 2023). It is also measured in the Mystical Experience Questionnaire (MEQ - MacLean et al.,

2012; Barrett, Griffiths, 2018), the 11 Dimensions Altered States of Consciousness Questionnaire (11D-ASC - Dittrich, 1998; Studerus et al., 2010), and the Psychedelic Change Questionnaire (PCQ-26 - Brouwer, Carhart-Harris, 2021).

10. EG. *Kogesin "enda" või oma ego hajumist.*

Mitte rohkem kui tavaliselt ○ ○ ○ ○ ○ ○ *Täielikult*

I experienced the dissolution of myself or my ego.

Not more than usual○ ○ ○ ○ ○ ○ Completely

Note: This question measures Ego-Dissolution, the sensation that one's sense of self ceases to exist. This dimension is also assessed by the Ego-Dissolution Inventory (EDI - Nour et al., 2016), the 11 Dimensions Altered States of Consciousness Questionnaire (11D-ASC - Dittrich, 1998; Studerus et al., 2010), and the Psychedelic Change Questionnaire (PCQ-26 - Brouwer, Carhart-Harris, 2021).

11. RA. *Kogemuse ajal tundsin rahu ja vaikust*

Mitte rohkem kui tavaliselt ○ ○ ○ ○ ○ ○ *Täielikult*

During the experience I felt calm and quiet.

Not more than usual○ ○ ○ ○ ○ ○ Completely

Note: This experience measured peace and tranquility, which may serve as a potential mechanism against depressive, anxious symptoms (Majic, et al. 2023). This dimension is also assessed by the Mystical Experience Questionnaire (MEQ30 - MacLean et al., 2012; Barrett, Griffiths, 2018), the 11 Dimensions Altered States of Consciousness Questionnaire (11D-ASC -

Dittrich, 1998; Studerus et al., 2010), and the Psychedelic Change Questionnaire (PCQ-26 - Brouwer, Carhart-Harris, 2021).

12. UH. *Kogemuse ajal tundsin ühtsust end ümbritsevaga*

Mitte rohkem kui tavaliselt ○ ○ ○ ○ ○ ○ *Täielikult*

During the experience I felt connected with what surrounds me.

Not more than usual○ ○ ○ ○ ○ ○ Completely

Note: This experience described a sense of connectedness or unity with the surroundings. This aspect of psychedelic experiences has been extensively measured in various instruments, including the Mystical Experience Questionnaire (MEQ30 - MacLean et al., 2012; Barrett, Griffiths, 2018), the 11 Dimensions Altered States of Consciousness Questionnaire (11D-ASC - Dittrich, 1998; Studerus et al., 2010), the Psychedelic Change Questionnaire (PCQ-26 - Brouwer, Carhart-Harris, 2021), and the Ego-Dissolution Inventory (EDI - Nour et al., 2016).

13. TA. *Kogemuse ajal tundsin sügavat tähenduslikkust.*

Mitte rohkem kui tavaliselt ○ ○ ○ ○ ○ ○ *Täielikult*

During this experience I felt deep meaningness

Not more than usual○ ○ ○ ○ ○ ○ Completely

Note: This experience measures signs of Apophenia, a symptom commonly reported after psychedelic drug use (Evans et al., 2023; Luke, 2012). An interesting paradox emerged with this question, as subjects who described it in the commenting space tended to assign it a low score. This question should be rephrased, particularly considering that the term "deep" was perceived as excessive.

14. SE. *Tegelesin enda sees toimuvaga.*

Mitte rohkem kui tavaliselt ○ ○ ○ ○ ○ ○ *Täielikult*

I dealt with what went on inside me.

Not more than usual○ ○ ○ ○ ○ ○ Completely

Note: This question measured introspection, encompassing meta-cognition, self-examination, and the overall observation of one's own mental and emotional processes. This dimension could potentially serve as a working mechanism against depressive and anxiety symptoms, promoting psychological flexibility (Wolff et al., 2022). Similar aspects are assessed in the Acceptance/Avoidance-Promoting Experiences Questionnaire (APEQ - Wolff et al., 2022), the Psychological Insight Questionnaire (PIQ - Davis et al., 2021), and the Psychedelic Change Questionnaire (PCQ-26 - Brouwer, Carhart-Harris, 2021).

15. KE. *Mulle tundus, et mul pole enam keha.*

Mitte rohkem kui tavaliselt ○ ○ ○ ○ ○ ○ *Täielikult*

I felt like I didn’t have a body anymore.

Not more than usual○ ○ ○ ○ ○ ○ Completely

Note: This question measures disembodiment, capturing the sensation of feeling like one is out of their body. This dimension is also assessed in the 11 Dimensions Altered States of Consciousness Questionnaire (11D-ASC - Dittrich, 1998; Studerus et al., 2010).

16. SU. *Kogemus pani mind mõtlema surmale.*

Mitte rohkem kui tavaliselt ○ ○ ○ ○ ○ ○ *Täielikult*

Experience made me think about death.

Not more than usual○ ○ ○ ○ ○ ○ Completely

Note: This question explored thoughts of death, and similar inquiries are present in the Psychological Insight Questionnaire (PIQ - Davis et al., 2021) and the Psychedelic Change Questionnaire (PCQ-26 - Brouwer, Carhart-Harris, 2021). During the questionnaire analysis, it emerged as the least correlated with other questions. An intriguing paradox surfaced with this question: subjects who left comments about thinking of death tended to assign it low scores. Rephrasing may be necessary for more accurate results.

17. HIL. *Tunnen, et efekt jätkus ka pärast virtuaalreaalsust.*

Mitte rohkem kui tavaliselt ○ ○ ○ ○ ○ ○ Täielikult

feel like the effect continued after virtual reality.

Not more than usual○ ○ ○ ○ ○ ○ Completely

Note. This question gauged whether the effect continued after the experience ended or not. In data analysis, this question was disregarded because it did not measure the overall psychedelic effect but rather assessed an interesting aspect of the experience.

18. Comment: At the end of the questionnaire, subjects had the option to leave comments. While not mandatory, it was strongly recommended.

Appendix C. Comment Encoding Principles

Comments were encoded on a binary scale. It got one point if it mentioned the psychedelic effect of the experience. If it was about anything else it got zero points. Exact coding schema is brought out below. When the comment included descriptions of both, one point and 0 point criteria it was given a point since it described experience in mentioned psychedelic dimensions. In the beginning of the procedure two encoders were included, but one disregarded the position. As nobody else volunteered the work was finished by one encoder.

The comment got one (1) point if:

- It described sacredness, finds surrounded by something holy
- It described ineffability
- It described unity
- It described ego-dissolution
- It described disembodiment
- It described finding inner peace
- The subjects gave meaning to meaningless abstract things
- It describes thinking about death
- It described revelation
- If it described introspection
- It describes transcendence in space and/or time
- It described being connected with everything and/or everyone else

The comment got zero (0) points if:

- It was about subject being dizzy
- It described or commented on the mechanics of the experience
- It said that the experience was tiring
- It was about positive or negative affect
- It described being drunk
- It described anything else, but not the aspects of psychedelic experience mentioned above.

Käesolevaga kinnitan, et olen korrektselt viidanud kõigile oma töös kasutatud teiste autorite poolt loodud kirjalikele töödele, lausetele, mõtetele, ideedele või andmetele. Olen nõus oma töö avaldamisega Tartu Ülikooli digiarhiivis DSpace.

Madli Kaljo