1. Title of the Project

VRcreativity: The Neural Correlates of Creative Ideation and Cognitive Absorption in Virtual Reality Environments

2. Coordinators

Dr. Maryam Alimardani
Department of Cognitive Science and AI (CSAI), TSHD

Dr. Alwin de Rooij
Department of Communication and Information Sciences (CIS), TSHD

3. Introduction and theory

1.1 Motivation

Creative ideation, the ability to generate ideas that are original yet useful (Runco & Jaeger, 2012), enables us to live healthier lives, enjoy the latest technologies, and be deeply moved by ground breaking art (Abraham, 2018). New media design has made a large impact on how people generate creative ideas, which potential and effects we are only now starting to understand (Literat & Glaveanu, 2018). People learn to understand a problem by searching information in Google, form and implement their ideas digitally in multimodal and interactive ways, and collaborate in virtual spaces at any time and in any place. Yet, the potential of new media for supporting creative ideation (Frich et al., 2019) and the process under which the brain responds to these new environments is still poorly understood (Abraham, 2018). Expertise at TSHD in both creativity and design research (CIS: NMD) and emerging technologies and cognitive science (CSAI) suggests that collaboration between departments at TSHD can uniquely contribute to this open scientific problem.

1.2 VR and creativity

Virtual reality (VR) is a new medium of particular promise for supporting creative ideation. Ever since becoming available to the larger public, applications for VR to enable creative work have skyrocketed (see for instance Alexandra, 2017). Indeed, emerging evidence shows that virtual reality affordances enhance creative idea generation (Guegan et al., 2019; Wang et al., 2018; Yang et al., 2018). For example, Yang et al. (2018) asked participants to draw a wearable technology on an anthropomorphic figure that would innovate everyday life in an immersive virtual reality environment or on paper. Their findings showed that generating ideas in an immersive VR environment led participants to generate more creative ideas than with pen and paper. This was explained by positive effects of virtual reality use on factors such as focus and flow. However promising, these findings are preliminary, which calls for both replication and a deeper understanding of the mechanisms that underlie this relationship between virtual reality and creative idea generation.

1.3 VR and Cognitive absorption

In order to assess a user's product within a new technology including creative quality of idea generation, one needs to address the technology usage behavior such as perceived usefulness and engagement. A multi-dimensional scale that measures the perceived usability of a new information technology is cognitive absorption (CA) (Agarwal & Karahanna, 2000). CA, which is very similar to the concept of flow (Nakamura & Csikszentmihalyi, 2014), is defined as the state of deep involvement in the adoption of a new medium and hence provides insight into user's intrinsic motivation related to technology usage behavior. The scale has five constructs, namely temporal dissociation (the inability to register time passage), focused immersion (the experience of total engagement), heightened enjoyment (the pleasurable aspects of the interaction), control (user's perception of being in charge of the interaction), and curiosity (the extent to which one's sensory and cognitive curiosity is aroused).

Previous research suggests that, in online environments, higher cognitive absorption leads to increased creativity, as well as increased learning, perceived behavioral control, and positive affect (Leong, 2011; Saadé & Bahli, 2005; Zaman et al., 2010). Moreover, a likely relationship exists with the explanatory relationships found by Yang et al. (2018) and the subscales underling cognitive absorption (Agarwal & Karahanna, 2000). As such, it is plausible that CA can explain central aspects of the relationship between VR and enhanced idea generation ability. However, very little is known about the state of CA in VR environments given that VR research mostly focuses on domain-specific concepts such as presence, embodiment and immersion. More importantly, an explicit relationship between CA and user performance on a creative task specifically in VR environments has never been established in the past.

1.3 EEG: an objective measurement of creative ideation and cognitive absorption

In addition to subjective measurements of user perception and creative ideation performance, an objective measurement of brain activity can contribute to our understanding of the neurocognitive mechanism that underlies such processes during interaction with a new digital medium such as VR.

In the past, neuroscience of creativity has been studied using non-invasive brain imaging techniques such as electroencephalograms (EEG). Literature suggests that alpha-band activity plays a key role in the creative process (Fink et al., 2006; Martindale et al., 1984; Fink et al., 2001; Benedek, 2018; Jauk et al., 2012), although other frequency bands, such as theta and gamma also serve critical functions (Stevens and Zabelina, 2019).

However, empirical evidence for neurophysiological correlates of cognitive absorption are very scarce, and mainly in digital platforms other than VR. For example, Léger et al. (2014) found a positive relationship between CA and alpha/beta activity in an online learning setup. Other studies have investigated EEG activity of game players by measuring subconstructs of CA such as enjoyment (Abujelala, 2016), or similar concepts such as flow (Berta et al., 2013; Plotnikov et al., 2012) and motivation (Derbali & Frasson, 2010).

Today, a wealth of VR research exists on the contribution of presence and embodiment to performance outcomes in virtual spaces. However, no studies in the past has employed CA as a subjective measure of VR experience and examined its contribution to creative idea generation in virtual spaces. Moreover, research on brain activity changes during virtual interactions and creative task in VR is particularly rare and inadequate. Therefore, we see a gap in the existing literature regarding the impact of VR on creative ideation performance, its relationship to cognitive absorption, and the contributing cognitive and neural mechanisms that underlie such processes.

1.4 Research questions

To address this open scientific problem, the following research questions (RQs) are raised;

RQ1: What is the relationship between creative ideation and cognitive absorption in VR environments?

RQ2: What are the neural correlates of the interaction between cognitive absorption and creative ideation in virtual reality?

To answer the above RQs, we propose the following study as collaboration between CSAI and CIS departments.

4. Proposed study

2.1 Design

40 participants will be recruited to participate in a within-subject experiment. They will be asked to generate ideas in two conditions with two different media types; 1) VR and 2) computer screen. In the VR condition, a virtual reality space is presented to the participants through a head mounted display and participants will see virtual objects before them (Fig. 1). In the computer screen condition, participants will see images of the objects on a computer screen. The objects presented in the two conditions will be different.

2.2 Creative Ideation Task (CIT)

To assess creative idea generation, the alternative uses task (AUT) will be employed (Guilford, 1967). In this task participants will be instructed to generate as many creative uses as they can for a set of commonly found objects. In each condition, participants generate creative uses for five different objects (e.g., a box, newspaper, or plate). For each object they have 60 seconds to generate their uses. In the virtual environment, objects for which ideas need to be generated will be present in the virtual space (Marinussen & de Rooij, 2019). Participants will be guided to each object in random order, after which they spend their 60 seconds generating their uses. To ensure accurate EEG measurement (see below), participants are asked to remember their uses, which they can report by writing these down after performing each AUT (Vartanian et al., 2019). Three independent raters will score the originality and usefulness of each generated use on a five point Likert scale (Beaty et al., 2019).

Fig. 1. Example of a previously used virtual environment (Marinussen & de Rooij, 2019) where people are asked to generate new uses for a common object (in this figure, a box).

2.3 Cognitive Absorption (CA)

Participants will report their CA level at the end of each condition using the CA standard questionnaire (Agarwal & Karahanna, 2000). The relationship between CA level and performance on the creative ideation task will be investigated.

2.4 EEG recording

A wireless EEG cap with 32 electrodes (g.Nautilus, gtec company, Austria) will be used to collect brain signals from all areas of the brain (The EEG acquisition system belongs to MindLabs and is available to the CSAI researchers). This EEG cap can be used together with a VR head-mounted display (Fig. 2). Participants' brain activity will be captured before (Pre-baseline), during (CIT) and after (Post-baseline) the idea generation task. For each individual the difference in spectral band powers (theta, alpha, beta, and gamma activity) from the Pre-baseline to CIT phases and from CIT to Post-baseline phases will be computed and compared between the two conditions (i.e. VR vs. Computer screen). Additionally, a correlation analysis will be performed on the EEG features and CIT performance as well as EEG features and CA levels.

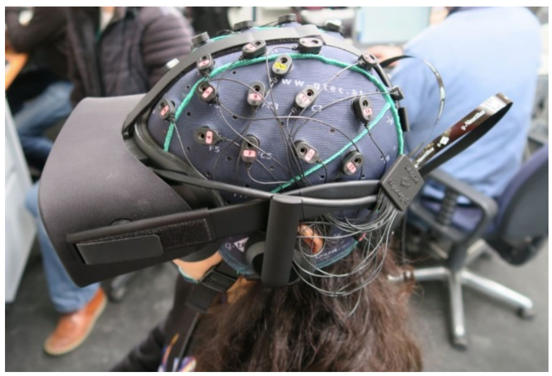

Fig. 2. Experimental setup during the VR condition

5. Justification of collaboration between CSAI and CIS: NMD

The proposed study requires the brining together of skills acquired uniquely in the master programs of CSAI (EEG, advanced data analysis, technical implementation of virtual reality environments) and CIS's New Media Design specialization (Creative thinking processes, visual and interaction design of virtual reality environments).

3.1 Applicants' profiles

Maryam Alimardani specializes in human-technology interaction and brain-computer interfaces. In her research she analyzes behavioral and physiological responses (such as EEG, heart rate, sweat response, etc.) of users during their interaction with a computer/agent and develops adaptive systems that use such input signals from the user for a better communication. She is an assistant professor in the Department of Cognitive Science and Artificial Intelligence (CSAI), Tilburg University and teaches the Virtual and Augmented Reality (VAR) course in the Data Science and CSAI master tracks. She has received a PhD in Innovative System Design from Osaka University, Japan.

Alwin de Rooij studies creativity: The thinking processes that make the creation of new, useful, and elegant ideas, solutions, and products possible. His research explores fundamental questions about the effects of emotion, unconscious cognition, and prediction on creative thought; and he actively pursues the development of tools and technologies that can help people to get more out of their creative capabilities. Alwin is an assistant professor at the Department of Communication and Cognition, Tilburg University, and teaches at their New Media Design program. He received a PhD in Creativity Science from City, University of London, an MSc in Media Technology from Leiden University, and a BFA in Autonomous Art from the Royal Academy of Art, The Hague.

3.2 Research Trainee Profile

Trainee 1 is a Ma student who has knowledge -or is interested- in cognitive science and brain imaging techniques. The research trainee will collect EEG signals during the experiment and will perform feature extraction and data analysis. S/he will assist Trainee 2 in the development of the VR environment. Therefore, a certain level of programming skills is required and experience with signal processing is a plus. This research theme is particularly suitable for students enrolled in the CSAI program.

Trainee 2 is a Ma student who has knowledge of – or is interested – in virtual reality and ideally in creativity and design research. The research trainee will develop and design a 3D virtual environment to enable EEG data collection. Therefore, a certain level of design skills is necessary. S/he will be required to assist data collection during experiments so an interest in EEG is a plus. S/he will be also responsible for the analysis of questionnaire data. This research theme is therefore particularly suitable for the new media design students enrolled in the CIS program.

Applicants should send their resume and a motivation letter to the following email addresses:

Alwin de Rooij <AlwindeRooij@uvt.nl>
Maryam Alimardani <M.Alimardani@uvt.nl>

6. Project timeline

Sep 2019: Start of the project
Oct 2019: Preparation of experiment material, start data collection.
Jan 2020: End of data collection, start processing EEG data and questionnaire results
Apr 2020: End of data analysis, perform statistical and correlation analysis
May 2020: Writing up the report
Jun 2020: End of the project

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