The effect of mediated plants on a divergent thinking test in virtual reality

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Graduation Thesis

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Abstract

Plants are incorporated in our daily lives in different ways, they are placed in our homes, outside in parks but also in our offices. In multiple studies, it has been proven that they can reduce stress, increase longevity, have positive physical effects and even enhance/stimulate creativity. But what would happen if the plants were enhanced in a way that it could lead to even a greater creativity boost? This question is investigated by having two groups of (n=30) participants take part in a drawing game in virtual reality. Two virtual reality rooms were created, one for each group. Room 1, the normal room, had normal green plants and Room 2, the mediated room, had plants that were mediated by using different colors that do not occur in nature. The participants would take part in a drawing game in the virtual environment, that challenged their creative abilities. All the created drawings were collected as images and the names of the drawings given by the participants were written down. These images were scored based on originality, elaboration, the abstractness of the title, originality and the number of colors they have used. Both groups were compared with each other and the result was that the participants in the group with the mediated plants scored significantly higher. These results suggest that mediated plants in a virtual reality environment could boost one's creativity.

1 Introduction

Several studies have concluded that plants have a positive effects on people regarding productivity and stress reduction. More studies about plants and their effects on productive and stress reduction have been done, but the positive effect of mediated plants on people's creative performance is studied less often.

This study is taking a new approach where the plants have been mediated by giving the leaves and stems different and unnatural colors. The motivation to choose mediated plants is to still have the possible creative effect of the structure of the plant but change them with different colors. The possible creativity-enhancing effect was tested on participants taking part in a creative drawing game in Virtual Reality. The game that is used to score the participants is a simplified version of the Torrance Test of Creative Thinking(TTCT) (Almeida et al, 2008).

This paper will first start with related work regarding the effects of plants and nature on human beings, examples that made people more creative, why VR could be a medium that facilitates the enhancing of one's creative performance and which test is used for the measuring of the creative ability of the participants.

After the related work, the method of the experiment is explained where one can read the research framework and the setup of the experiment. Next, the results of the experiment are described. This paper ends with the discussion and conclusion.

2 Related work

The related work consists of previous research that is used to base this experiment on. Firstly, research on the effect of nature on humans will be described, secondly research on nature in our living and working environment will be described, thirdly research on mediated nature will be described, fourthly research on Virtual Reality as a medium for scientific experiments will be described. At the end of the section, related work will be described on how one could test creativity.

2.1 The effect of nature on humans

To be able to experiment with plants, it's important to understand why nature has a positive effect on humans. A term that is used for this positive effect is called Biophilia. Biophilia is the hypothesis that we as humans are inherently inclined to affiliate with nature and unconsciously seek a connection with other living organisms (Grinde & Patil, 2009; Wilson, 2009). This connection between humans and nature has been there since the beginning of mankind because we as humans were able to survive if we were near green environments.. These green environments gave humans shelter, a food resource and an indication of water. Next to survival, there are more positive effects studied and reported: one study concluded that exposure to nature has a positive effect on stress reduction (Ulrich et al., 1991), another that exposure to nature increases attention span (Berman, 2009), a third that it leads to increased longevity (Takano, 2002) and a fourth study reported that exposure to nature contributes to physical health benefits (Pretty, J et al, 2006).

But these studies didn't describe what causes these positive effects, only that the effect occurred. A study that did try to explain it was conducted by Roger Ulrich. The study describes 4 possible causes. The first is that being in nature has a correlation with physical activity that enhances one's health. The second one is the social aspect of being together in nature: people go hiking, sit in parks, have barbeques or go swimming in lakes. All these activities bring joy and closure with other people. The third option is that it could give people a brief or longer escape from their daily activities and demanding tasks. The fourth possibility pointed out by Ulrich is that humans who need to perform tasks while surrounded by or when interacting with nature, experience a positive effect on their psychological state (Ulrich, 1999).

2.2 Nature in our living and working environment

Previous studies on the effect of having nature in our presence, while doing tasks, will be described next. Could we add nature elements in our environment? For example, plants to our houses and the working environment to have that same positive effect?

A study reported that tiredness, health complaints and sickness decreased in working environments where plants were placed (Dijkstra, Pieterse & Pruyn, 2008). The researchers pointed out that the positive effect was either generated by the increase of fresh air or the pleasing visual aesthetics of the plant in the environment. This pleasing visual aesthetic effect was also studied by a different group of researchers and they reported that the pleasing visual aesthetic of a plant was even better than man-made objects like a designer lamp or an abstract painting (Lohr & Pearson-Mims, 2000). They reported that plants have a greater stress relief effect, a higher increase of attention power and made people perceive the room more pleasant, cheerful and inviting.

But what is the effect of interaction with a plant, feeling the plant or moving it? This question was studied by a team that divided participants into two groups. One group needed to perform tasks on a computer and the other group was asked to transplant an indoor plant. After they were done with their tasks they were asked to switch. The psychological evaluation was done by measuring heart rate and blood pressure and filling in a form afterwards. The experiment showed that the participants felt more soothed, comfortable and had a lower heart rate when they were transplanting the plant than when they performed the computer tasks (Lee, Lee, Park & Miyazaki, 2015).

Roger Ulrich, who is a behavioral scientist and director of The Centre for Health Systems and Design at the University of Texas, conducted a study that took 8 months. Participants were asked to perform creative tasks and attention-demanding tasks. The participants were divided into three groups: one needed to perform the tasks in an environment full of plants and flowers, the second in an environment decorated with sculptures and the third in an environment without any decoration. The result was that the participants in the group with plants and flowers scored higher on idea generation, problem-solving skills and came up with more original solutions (Ulrich, Varni, 2003). Roger Ulrich has shown that there is a positive effect of plants on creativity, but could it be possible to enhance that affect even more?

2.3 Mediating nature

These findings of the positive effect of plants in indoor environments can be seen as the important stepping stone that lies at the hearth of our experiment.
Given the above, we assume that plants in an indoor environment have a positive effect, but could it be possible to mediate the plant in such a way that the positive effect increases even more? In other words, can non-realistic colored plant have a higher positive effect than a normal green plant? This could open up a new field of experiments regarding mediated nature and the effects on human creative performance.

The idea of mediated nature came from a movie from 1992 called the Lawnmower written by Stephen King. The lawnmower is a movie where actor Pierce Brosnan is a scientist that thinks that Virtual Reality holds the key to the evolution of the human mind. Jeff Fahey is the actor who plays Jobe Smith, a middle-aged man who has the cognitive mind of a child and mows the lawns in the neighborhood. The scientist asked Jobe if he wants to play a virtual reality game in his experiment room as seen in figure 01.

Figure 01: Jobe (left) and the scientist (right).

Jobe accepts the invitation and plays multiple games and likes it a lot, but he always gets stuck on a certain level because of his lack of cognitive intelligence. The scientist has an idea for this and asks if Jobe wants to play a different game that will increase hist cognitive intelligence. Jobe accepts and starts playing multiple games in the virtual world. Jobe gets smarter and smarter every day until he even gets paranormal gifts, for example the ability to read minds of people in real life and moving the lawn mower with his brain. Jobe will eventually be smarter than the scientist and starts to go his own way. In case the reader of this paper considers watching the movie, the remainder of the plot will not be revealed. Virtual reality gave the scientist in this fictional movie the possibility to mediate to the environment in such a way that Jobe was inspired and could experience things that are not possible in real life (King, S. 1992). The combination of mediated plants and the use of virtual reality is not yet been done and therefore it makes it an interesting approach.

2.4 Virtual Reality as a medium for scientific experiments

Virtual reality lends itself perfectly for scientific experiments. It gives the possibility to create the same experiences and only tweak miner details to test if the details have an influence on the results, it is cost efficient because adapting colors of realistic looking plants only requires a few clicks with in the virtual reality software instead of creating, painting and testing the color of plants in real life. And as computer scientist and internet pioneer Ivan Sutherland said in his essay: "A display connected to a digital computer gives us a chance to gain familiarity with concepts not realizable in the physical world. It is a looking glass into a mathematical wonderland" (Sutherland, 1965). One can interpret a virtual reality headset as the looking glass.

An example in which virtual reality has been proven to be a good medium for science is a study that had two groups of Chinese students who were instructed to move through a series of corridors in a virtual reality environment (Wang et al, 2018). They could move forward by clicking forward and control the direction with their body movement. The difference between the two groups was that one group would face walls between the corridors that they needed to break before they could move further. The other group did not have walls and could just continue to the next corridor. After participants finished the exercise in virtual reality, they were instructed to perform an alternative uses task to assess their creativity. The group that broke the walls scored higher on the alternative uses tasks. The researchers speculated that the participants experienced a breaking the rules affect that gave them a sense of freedom that could result in more creative thinking.

Another reason VR lends itself perfectly for scientific experiments is that it can mimic the idea of presence. A non-scientific example of this concept of presence is what Designer Neil Stevenson experienced. For his work he moved a lot, from San Francisco to London and to other cities around the world. Every time he arrived in a new city, he experienced a period that he called a "creative honeymoon". In that period everything felt fresh and inspiring: the people, the environment, the way of working, it all generated a head full of new questions and sparked his creativity. It felt like his brain received an upgraded operating system. Eventually, after a few months, it all felt familiar and the creative honeymoon was over. The exploratory mindset was gone, and routine was kicking in. He began to wonder how he could achieve this creative honeymoon again without needing to travel to a new city and therefore leaving his family and friends behind. While wondering, one of his colleagues asked him if he would like to try out VR. He was quite skeptical about VR but did give it a try. After multiple experiences of virtual cities, nature landscapes and games, he suddenly had the same creative honeymoon feeling again. He felt a presence in a different environment via the virtual reality technology. To understand and to create a virtual reality environment where participants can feel that they are present, it is important to understand the pillars that create the experience of presence in Virtual Reality.

2.5 Presence in virtual reality

Based on the book "The VR Book: Human-Centered Design for Virtual Reality" of Jason Jerald there are four important pillars that simulate presence in VR (Jerald, 2015). The first and the most important of the four is the illusion of physically being in an environment. This can be achieved when the room and objects are perceived as the real world. To perceive this, one should view this virtual world with a high frame rate, a good calibration of the device and low latency.

The second part is self-embodiment, this is the part where participants feel that their body is aligned with the VR environment. When grabbing an object, it should look like they have it in their hands. When they put on the headset the length of the person must be used to determine the viewing angle of the person. For example, if you would put a man with a length of 196 cm in an experience where the height of the viewpoint is much lower one could feel that it is not correct.

The third pillar is the illusion of physical interaction. Just moving around is not enough, it's important to be able to interact with the environment. It could be that one could press on an object and get audio, visual or haptic feedback.

The last pillar that is important based on the book of Jason Jerald is the illusion of social communication. People are social creatures and are inclined to have social interactions. This can be achieved by having objects, human-like characters or other things that one could have social interaction within virtual reality.

2.6 Testing creativity

One of the most common and worldwide ways to test creativity is the Torrance Test of Creativity Thinking (TTCT) created by E. Paul Torrance (Almeida et al, 2008; Torrance, 1980). The TTCT is based on Guilford's model of divergent thinking. The test is used to assess an individual's creative capacity. The test consists of multiple simple divergent thinking tests that can be divided into three categories: the verbal tasks using verbal stimuli, the verbal tasks using non-verbal stimuli and the non-verbal tasks. The outcomes of the test are scored based on four factors: fluency, resistance to premature closure, originality, and elaboration.

With the scoring, one could create a creativity scoring index that has the following purposes:
1. To understand the human mind and its functioning and development
2. To discover effective vases for individualizing instruction
3. To provide clues for remedial and psychotherapeutic programs
4. To evaluate the effects of educational programs, materials, curricula, and teaching protocols

Regarding the research that has been done, it's important to elaborate on the non-verbal tasks of the TTCT and the purpose to evaluate two conditions and how they affect the outcome of the score. Examples of the non-verbal test are: Incomplete figure tasks, picture construction tasks or shapes tasks, circle and squares tasks. In this experiment, the picture construction tasks are used and will be explained further. The specific task is that participants are given a starting shape and need to use this shape to construct a shape where the starting shape is part of it. When they are done, they need to write a name describing what the creation means. The challenge is to generate as many ideas as possible (fluency), to elaborate on the picture by adding different objects (elaboration) and use an abstract title to show their imagination with the created object (Abstractness of the title).

3 Method

In this chapter, the method will be described. In the following, we will describe what the experiment will try to investigate, how the experiment is set up and how the scoring is done regarding the created drawings of the participants.

3.1 Research description

Given the above related research, plants have a positive impact on humans in working and in household environments. Plants can have a positive effect on both physical and psychosocial aspect of humans, for example on their creativity. Virtual reality has lent itself multiple times for being a good platform to use for scientific experiments regarding creativity and immersion. These both findings created the inspiration to set up an experiment with the following research question:

"Could mediated plants have a positive effect on a divergent thinking test in virtual reality?"

3.2 Setup of the experiment

3.2.1 The participants and the survey

This experiment was done with participants who were gathered via social media and via the social network of Stijn van Vilsteren. The participants were asked to take part in a scientific experiment at the office location of WeMakeVR in Amsterdam. Every participant was booked into a slot of one hour. When participants arrived at the location, they did not know what the content or the research question was to make sure that they weren't biased. They were instructed to fill in a pre-survey. After six questions people were instructed to do the experiment in VR that had a maximum time of 35 minutes per person. Questions and statements 4 until 12 were filled in based on a scale from 1 until 5. 1 was strongly disagree and 5 was strongly agree. The questions and statements are shown in table 01.

#	Survey question
1	What's your age?
2	What's your gender?
3	What is the highest degree or level of school you have completed? If currently enrolled, highest degree received?
4	How experienced are you regarding virtual reality?
5	How often did you play games last year?
6	How experienced are you with drawing/sketching in real life?
7	I was afraid to make mistakes
8	In VR it is harder to be creative when drawing than in real life.
9	I was inspired by the environment to get more creative
10	The room I was in felt realistic.
11	It felt naturally to draw with the markers on the whiteboard.
12	Could you recall and write down what you saw in the room?

Table 01: Survey questions

3.2.2 The technical system

The technical system that made it possible to conduct this experiment consists of the following hardware objects:

1. A HTC Vive Headset
2. Two HTC Vive controllers
3. A personal computer
4. Two Vive sensors to determine where the participant was located
5. A couch that was also in the virtual world where participants would start from.
6. A personal computer to fill in survey
7. A separate computer for the researcher to take notes

3.2.3 The test in virtual reality

To test the hypothesis, it was necessary to have two different virtual environments, one with mediated plants and one with normal plants. In this research, we will further refer to the mediated room and the normal room. We aimed to have an equal amount of participants for both rooms. The first person was put in the normal room and the next person was put in the mediated room. The mediated room is a

living room with plants that have unnatural colors. The normal room is exactly the same room but with plants with normal colors.

3.2.4 The experiment step by step.

The participants are instructed to sit down on a coach in real life as seen in figure 02.

Step 1: introduction to the environment
After sitting down, the headset will be given and the participants put this on. The participants can now see that they are also sitting down in the virtual reality on a couch as seen in figure 03.

Figure 02: The place where the experiment was conducted.

Figure 03: The starting view (normal room)

The environment that can be observed is a living room with a kitchen, a tv area, windows to look outside, a working area with a laptop and a chair. Besides these normal living room objects, the participants can see a whiteboard and a small table with whiteboard markers in different colors. The whiteboard is attached to an open bookcase. In front, beside and in the bookcase are plants. As seen in figure 04.

Figure 04: The whiteboard, markers and plants (normal room)

Step2: Warming up

The participant was asked to stand up and explained that they could see a blue rectangle on the ground that marked their walking boundaries. Next, the participant was told to take a look around for 30 seconds. After the 30 seconds, they were explained that the whiteboard markers could be picked up and that this stage was a warming up round for 1 minute. After picking up the markers they were asked to practice drawing on the whiteboard. On the whiteboard one could read "Let's start with drawing these shapes in the boxes below" as seen in figure 05. Participants were given a minute to get familiar with writing on the whiteboard and they were asked to write their names on the whiteboard.

Figure 05: The warming up screen (normal room)

Step 3: Experiment stage: start of the test

The creative test started when the participant pressed a button on his right controller that would change the whiteboard default image to a new image. This image was a big black rectangle with a starting shape in the middle as seen in figure 06.

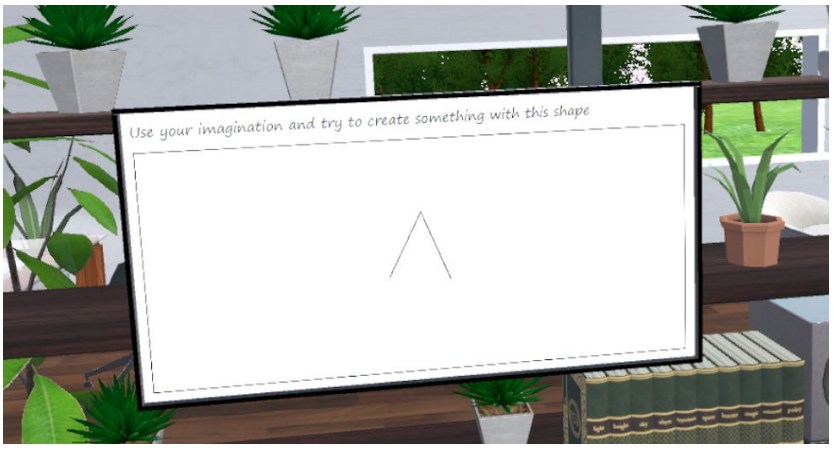

Figure 06: The shape to start with (normal room)

Participants were told to use the starting shape and make a drawing out of it. They were instructed to make a drawing of something that could exist in real life. Other than that, they were free to make whatever they wanted to. In addition, the participants were instructed to name their drawings with a title that would describe what the drawing was. The participants were told that they had a maximum of 35 minutes to create drawings, in total. They could choose from 3 starting shapes and were able to switch between these shapes. When they finished a drawing and had written down the name of the creation, they could move on to the next starting shape. When the experiment ended, they were helped with removing the headset and were instructed to go to the computer and fill in the past-survey questions.

3.2.5 Data collection during the experiment

When they moved to the next picture, the system took a screenshot of what the participants had created so it could be scored later. In addition, the system stored the amount of time it took the participants to create a drawing.
The participants could decide for themselves if they wanted to stop at any moment before the full 35 minutes were spent. After 35 minutes, the participants were stopped by the researcher. The amount of time spent on each drawing and the total time spent was also collected.

3.2.6 Whiteboard assets

The whiteboard and markers in this experiment were assets that were publicly available and created by Mark Marchlewicz. They needed some slight modifications to be able to take screenshots, have different starting images and work together with the HTC Vive and the Unity versions. One can find the assets online on his github (Marchlewicz,2019).

3.3 Grading the participants output.

The grading of the created drawings and their names was inspired by the Torrance Test of creative thinking. The participants' drawings were graded on the following factors shown in table 02.

Factor	explanation	scoring
Fluency	The amount drawings they created	Count the amount of drawings
Abstractness of the title	The titles were graded on a scale of 1 till 3 points	1 point was given if the title only consists of one noun (for example: Star) 2 points were given if they used a noun and added an adjective (for example: Rising star) 3 points were given if they used multiple nouns and an adjective (for example: The rising star of Bethlehem)
Originality	If another participant had created the same or a similar drawing within the whole dataset (n=60).	1 point was given if the created drawing would show up more than 3 times 2 points were given if 1-3 participants had created a similar drawing 3 points were given if no other participant had created a similar drawing
Elaboration:	The number of added objects and use of details in the created drawing besides the starting shape. Scale 1 till 3 points	1 point was given if a drawing only consists of one object (for example: a triangle) 2 points were given if more objects were added other than the starting shape (for example: a triangle and mountain) 3. points were given if the participant added more objects and used a high amount of detail (for example create dept, perspective, the illusion of movement)
Amount of colours used:	The amount of colors that the participants used in their drawing scale of 1 tot 6	the amount colors used equals the amount of points given

Table 02: Factor, explanation and scoring

4 Results

The experiment was conducted at the WeMakeVR office in Amsterdam in order to minimize the amount of environmental and setup changes to be sure that only the plants in the virtual environment would be different. The participants (n=60) were equally divided into two groups (n=30). All the participants were invited within one week and planned in the next week to take part in the experiment. The first person who took part was assigned to the Normal room and the second to the Mediated room and the third again to the normal room and so on until the 60th person. The two weeks of experiments took place in the month of January 2019.

4.1 Pre-experiment survey results

Before the VR experiment, participants were asked to fill in a survey. The results of this pre-survey can be seen in table 03. The average age of the participants was a bit higher in the normal room, participants who were in the mediated room were more experienced regarding virtual reality and were more experienced at drawing/sketching in real life. None of these results were significant different, see table 04.

	Group	N	Mean	SD
What's your age?	Normal Room	30	30.567	8.427
	Mediated Room	30	27.867	4.681
How experienced are you regarding Virtual reality?	Normal Room	30	2.567	1.547
	Mediated Room	30	2.933	1.388
How often did you play games last year?	Normal Room	30	3.267	1.258
	Mediated Room	30	3.000	1.259
How experienced are you with drawing/sketching in real life?	Normal Room	30	2.267	1.143
	Mediated Room	30	2.533	1.137

Table 03: Pre-experiment descriptives

	t	df	p
What's your age?	1.534	58.00	0.130[a]
How experienced are you regarding Virtual reality?	−0.966	58.00	0.338
How often did you play games last year?	0.821	58.00	0.415
How experienced are you with drawing/sketching in real life?	−0.906	58.00	0.369

Table 04: Pre-experiment Independent Samples T-Test

4.2 Experiment results

After the experiment, the drawings of each participant were scored on elaboration, originality, the number of colors used, the abstractness of the titles given, and fluency per participant was calculated. The second step is to determine if the results are significant. This can be done by computing an Independent Sample T-test. In other to do this test, it's obligated to have a normal distribution in both groups for each category (Kim T., 2015). To compute the distribution of each scoring group, histograms were made based on the normal room group, histograms on the left and the mediated group, histograms on the right. The histograms indicate that score categories Fluency and Abstractness of the titles aren't normally distributed as one can see in figure 7.

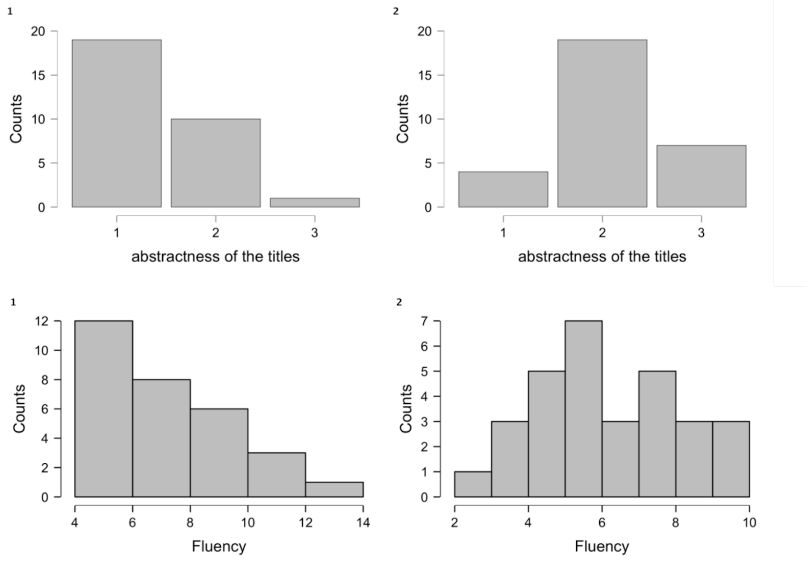

Figure 7: Histograms of Abstractness of titles and fluency,
Left is normal group and the right are the mediated group

The other categories, originality, elaboration and amount of colors, appear to be normally distributed as one can see in figure 8.

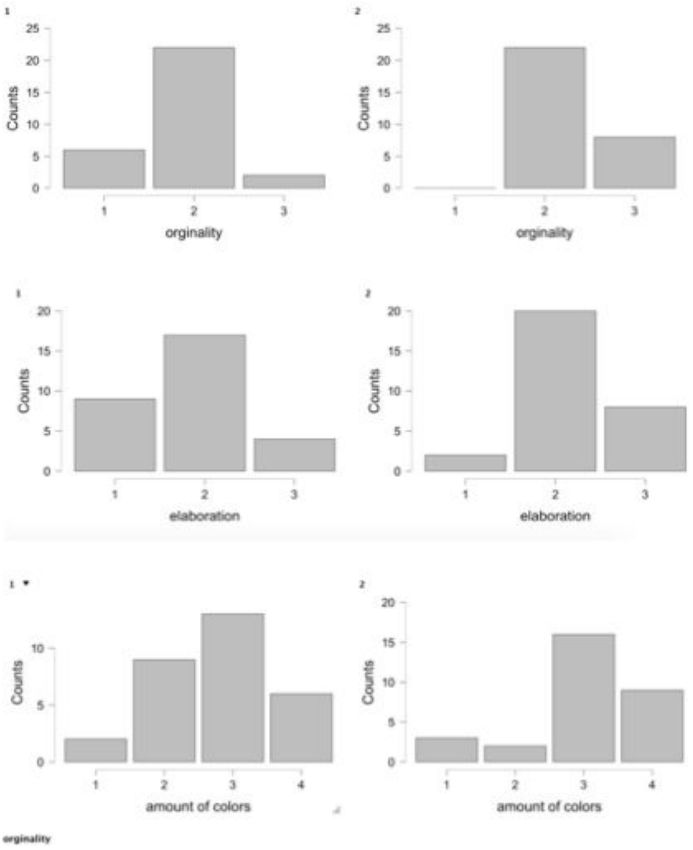

Figure 8: Histograms of originality, elaboration and amount of colors

Abstractness of titles and fluency are not normal distributed and cannot be tested with the Sample T test. It is possible to test not normal distributed data with a different test named Mann-Whitney (Ghasemi, A. 2012). Based on the analysis of distribution and determining the correct test, table 05 shows that the participants (n=30) who were in the mediated room scored significantly higher on: elaboration, originality and the abstractness of the titles. Fluency and amount of colors scored higher but not significantly. Table 06 shows that the scores of elaboration, originality and abstractness of the titles is significant and the amount of colors and fluency are based based on the Independent Sample-T test and the Mann-Whitney test, at the 0.05 significance level.

	Group	N	Mean	SD
Fluency	Mediated	30	6.633	2.025
	Normal	30	7.733	2.559
abstractness of the titles	Mediated	30	2.100	0.607
	Normal	30	1.400	0.563
amount of colors	Mediated	30	2.983	0.787
	Normal	30	2.697	0.735
orginality	Mediated	30	2.267	0.450
	Normal	30	1.867	0.507
elaboration	Mediated	30	2.200	0.551
	Normal	30	1.833	0.648

Table 05: Experiment scoring descriptive

	Test	Statistic	df	p
Fluency	Student	−1.846	58.000	0.070
	Mann-Whitney	348.000		0.129
abstractness of the titles	Student	4.628	58.000	< .001
	Mann-Whitney	700.500		< .001
amount of colors	Student	1.458	58.000	0.150
	Mann-Whitney	560.500		0.103
orginality	Student	3.231	58.000	0.002
	Mann-Whitney	606.000		0.003
elaboration	Student	2.362	58.000	0.022
	Mann-Whitney	583.000		0.024

Table 06: Experiment scoring Independent Samples T-Test & Mann-Whitney

4.3 Post experiment results

As seen in table 07 the mediated group people were more afraid to make mistakes, were more inspired by the environment to be creative and it felt more natural to draw with markers on the whiteboard. Participants in the normal room felt that the room was more realistic and stated that in VR it is harder to be creative when drawing than in real life. However none of these differences were statistically significant(table 08).

	Group	N	Mean	SD
I was afraid to make mistakes	Normal Room	30	2.000	1.083
	Mediated Room	30	2.200	1.064
In VR it is harder to be creative when drawing than in real life	Normal Room	30	2.933	1.230
	Mediated Room	30	2.667	1.093
I was inspired by the environment to get more creative	Normal Room	30	2.900	1.062
	Mediated Room	30	3.033	0.890
The room I was in felt realistic	Normal Room	30	3.700	0.952
	Mediated Room	30	3.300	0.952
It felt naturally to draw with the markers on the whiteboard.	Normal Room	30	3.100	1.155
	Mediated Room	30	3.367	0.999

Table 07: post experiment survey descriptives

	t	df	p
I was afraid to make mistakes	−0.722	58.00	0.473
In VR it is harder to be creative when drawing than in real life	0.888	58.00	0.378
I was inspired by the environment to get more creative	−0.527	58.00	0.600
The room I was in felt realistic	1.627	58.00	0.109
It felt naturally to draw with the markers on the whiteboard.	−0.956	58.00	0.343

Table 08: Post experiment survey Independent Samples T-Test

During the experiment, the amount time to create a drawing was measured. In table 09 one can see the total and the average amount of minutes per drawing and in table 10 if these scores were significant. The participants in the mediated group scored significantly higher on both aspects.

	Total minutes spent		Average minutes per drawing	
	Mediated	Normal	Mediated	Normal
Valid	30	30	30	30
Missing	0	0	0	0
Mean	25.800	22.333	3.433	2.733
Std. Deviation	7.107	7.680	1.431	1.660
Minimum	11.000	10.000	1.000	0.000
Maximum	34.000	39.000	6.000	7.000

Table 09: Average time per drawing and total time

	t	df	p
Total minutes spent	1.815	58.000	0.075
Average minutes per drawing	1.750	58.000	0.085

Table 10: Independent Sample T-Test

4.4 Correlations in the data

All correlations regarding the pre-experiment questions, the experiment results and the post experiment results have been checked. To keep this paper concise, only the noteworthy correlations are given.

To assess the relationship between the amount of drawings made and the average time per drawing, in both groups a Pearson product-moment correlation was computed. In the normal group there is a negative correlation between the two variables, $r = -0.643$, $p = <0.001$ and in the mediated group there was a negative correlation between the variables, $r = -0.372$, $p = 0.050$. This result suggests that participants who made more drawings spent less time average per drawing.

A positive significant correlation is measured between the average total amount of time and the amount of colors that were used in both groups. In the normal group there is a positive correlation between the two variables, $r = 0.600$, $p = <0.001$ and in the mediated group there was a positive correlation between the variables, $r = 0.384$, $p = 0.036$. This suggests that participants that spent more time used more colors.

A second positive significant correlation is measured between the average minutes per drawing and the abstractness of titles in both groups. In the normal group there is a positive correlation between the two variables, $r = 0.487$, $p = <0.006$ and in the mediated group there was a positive correlation between the variables, $r = 0.385$, $p = 0.036$. This suggest that participants who took more time per drawing scored higher in giving creative names to their drawings.

4.5 Qualitative results

Based on observations and notes, the following 3 qualitative results are worth sharing. Firstly, there were two kinds of drawings that all drawings could be divided into. In the first, participants used the whole whiteboard and created a landscape like drawing, used dept and created a story as seen in figure 09. The other category had people that only created a single object as shown in figure 10.

Figure 09: Landscape drawing

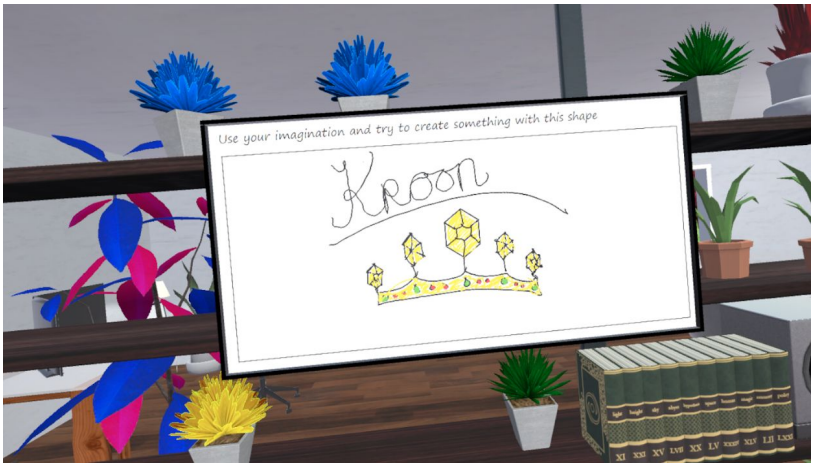

Figure 10: Single object drawing.

Secondly, multiple participants waited in front of the starting shape and thought a minute out loud before they started. Others started drawing as soon they saw the new starting shape appear.

The last observation is the amount of the similar drawings. In figure 11 one can see that with the starting shape of a diamond participants created a honeycomb, one more detailed than the other. The screenshot on the left is made in the normal room and on the right in the mediated room. When looking closely the drawing on the right has more perspective and added bees.

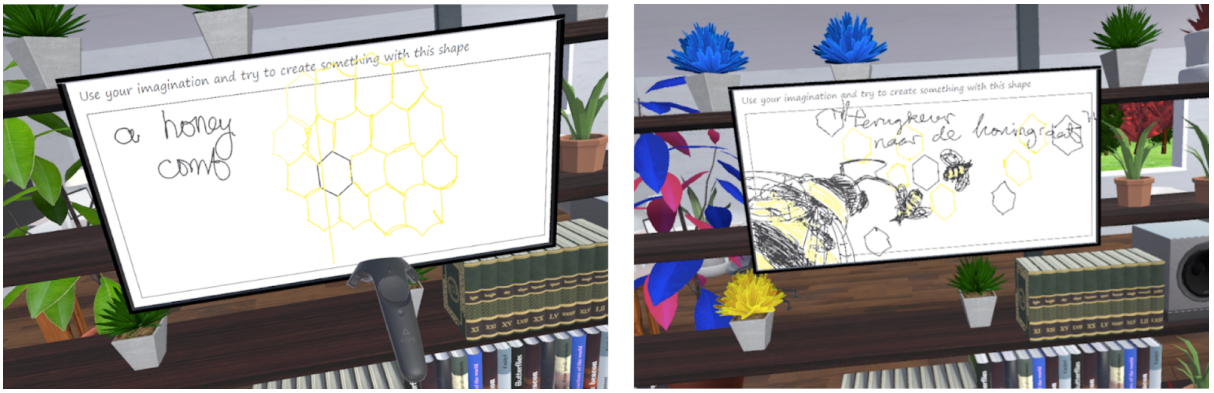

Figure 11: Screenshots of honeycombs drawings,
left in the normal room, on the right the mediated room.

In figure 12 one can see an image of two of the dozen clothespins that were drawn. Multiple participants had problems to start with the starting shape.

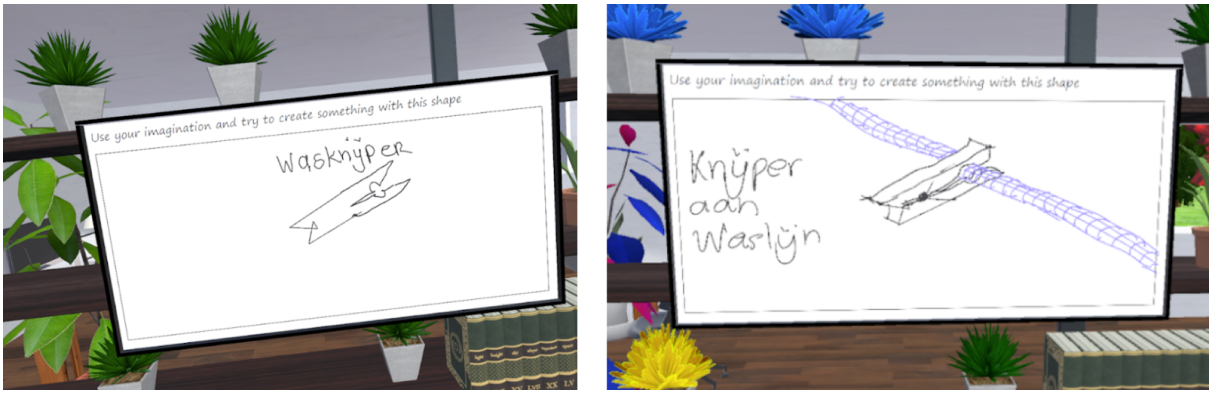

Figure 12: Screenshots of drawings of clothespins.

5 Discussion & future work

Based on the results, analysis and gathered feedback after the presentation, the following discussion points and ideas for future work are given.

5.1 Extra condition that would not have plants

After conducting this experiment, it would be also interesting to test with a third room, a room without any plants. The reason that this is not part of this experiment is that the focus was on the effect of the mediated plants and not if there is a difference between plants or no plants.

5.2 Visual plants are not real plants, only visual.

A question that was asked during the presentation of this research: “How could the positive effect of visual plant in virtual reality have the same effect as a real plant? You are not able to touch, feel or smell it.” This question is an important one but doesn’t take into consideration that the brain can be tricked. An example where one's brain was tricked by visual stimulation was a virtual reality boat tour through the canals of Amsterdam that people could experience. After the experience people asked the creator: “where did you put the fan because I thought I felt wind and the warmth of the sun?”. But the creator told that they didn’t have that fan. This is an example that one could feel something that isn’t there.

5.3 The scoring procedure

The results of the experiment showed that the drawings created in the mediated room scored significantly higher on four of the five factors, but it’s important to mention that the scoring of the drawings was done by the creator of this paper. There could be a chance that the scoring was influenced by prior knowledge of similar research. This would lead to higher scores for the drawings created in the mediated room. To improve this, it would be preferred to ask other people to score the drawings without knowledge of this research. Therefore, it’s important to mention that this research suggests a possible effect of mediated plants on the test and does not claim to have found a definitive conclusion.

5.4 Measuring the differences between starting shape times and completion

Because participants were able to switch between starting shapes, it was quite complicated to determine how long they took for a specific starting shape and compare them with the other group. This would be an interesting follow-up question and with a small adjustment to the experiment this would be possible to measure. To be even more precise, it would be interesting to check the time between the moment when the participant saw the starting shape and the moment when the participant started to draw. This could measure the amount of time people needed to think/get inspiration from their surroundings.

5.5 A different game in a different environment

Different games could be implemented instead of the drawing. This research uses one test and one game. Would there be a different outcome if participants would play different games? An idea for the

future would be implementing different games in different environments with plants, maybe a non-virtual world.

6 Conclusion

This experiment investigated the possible positive effects of mediated plants on the divergent thinking test based on the Torrance Test of Creative Thinking in virtual reality environment. The results show that participants who were in the mediated room scored significantly higher on the scoring factors: elaboration, originality and the abstractness of the titles. The factor fluency was lower than in the normal room but wasn't statistically significant. The results of the pre and post experiment survey questions were not significant and therefore could not be used to clarify the higher score in the mediated room. Given the results of this paper we could suggest that the mediated plants in the virtual reality environment did have a positive effect on the divergent thinking divergent thinking test.

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