Universiteit Leiden

Psychologie
Faculteit der Sociale Wetenschappen

Playing Creative Games Enhances Convergent Thinking

Name: Yannick de Winter
Student number: s1740326
Date: 29-06-2017
Supervisor: K. J. F. Olfers
Second reader: P. Haazebroek
Word count: 12.351
Cognitive Psychology
Thesis Msci Applied Cognitive Psychology

Can we enhance creativity? Creativity has been linked to gaming and to dopaminergic levels. And since sport also has a link to dopamine, in this study we researched the influence of gaming and sport on creativity. We set up two studies: first, we did an observational study to research if videogame experience is positively related to convergent creativity and furthermore if this relation also exists between sport and creativity. Thirty-three participants made four tests, measuring creativity: the Remote Associations Task (RAT), the Alternative Usage Task (AUT), Raven's Progressive Matrices (RPM) and the Pasta Task. We did not find such relation for gaming nor for sport experience. Also, playing more videogame genres did not result in people being more creative. In a second (explorative pilot) study we researched if playing creativity rewarding games can enhance people's creativity. Fourteen participants took the RAT, AUT and RPM at a pre- and posttest, while playing games in between (intervention). The intervention consisted of playing creativity rewarding games, music games, music games without music or playing no games at all. We expected the rewarding aspect of the creativity games to increase dopamine levels from pretest to posttest, as measured by Eye Blink Rate (EBR). We found that the creativity rewarding intervention had an effect on convergent thinking and that also the EBRs differed significantly. However, since our sample size was limited, these are 'preliminary results' which should be investigated further with a larger subject pool.

Playing creative games enhances convergent thinking

"Creativity is just connecting things. When you ask creative people how they did something, they feel a little guilty because they didn't really do it, they just saw something. It seemed obvious to them after a while. That's because they were able to connect experiences they've had and synthesize new things"

- *Steve Jobs*

As mentioned by Steve Jobs, people who are creative can come up with original ideas and make connections between seemingly unrelated subject matter and materials. But the education we receive in school is not interested in this particular set of skills. Instead, we all learn the same facts that have been around for hundreds of years and to think alike. Thinking different seems to be a sin. However, in order to solve many of the new world problems we actually need people who think differently than the majority. That is why we asked ourselves: "What if we could enhance creativity?"

Creativity is a broad concept and different researchers have different meanings for the concept of creativity. The most common used meaning for creativity in the field of psychology is that creativity consists of two types: convergent thinking and divergent thinking. Convergent thinking focuses towards deriving the (single) best (or correct) answer to a clearly defined question (Mednick & Mednick, 1972; Cropley, 2006). It is related to speed, accuracy, logic and accumulating information. One of the most important aspects of convergent thinking is that this method of thinking leads to a single answer, with no room for ambiguity. In daily life, convergent thinking can take place when you try to answer a specific question, for example: Which American actor plays the main character in House of Cards? To answer this question you have three cues that will help to find the answer: American, actor and House of Cards. Combining these three cues will lead to only one answer: Kevin Spacey. Convergent thinking is combining information and searching for the one factor that is associated with every piece. One of the first studies to investigate convergent thinking was done by On the other hand there is divergent thinking. Divergent thinking (Guildford, Christensen, Merrifield & Wilson, 1978) can be seen as the opposite of convergent thinking because divergent thinking focuses on generating as many appropriate answers as possible (Mccrae, 1987). Divergent thinking requires making unexpected combinations and transforming information into unexpected forms (Cropley, 2006). A good example of divergent thinking in daily life is brainstorming.

These types of creative thinking can be measured with two different tasks, the Remote Association Task (RAT) (Mednick & Mednick, 1972) for convergent thinking and the Alternative Uses Task (AUT) (Guilford, Christensen, Merrifield & Wilson, 1978) for divergent thinking. In the RAT a participant is presented with three words and is asked to supply a fourth word that is related to the other three. The three words are considered to be from 'remote associative clusters' and the fourth word is to provide a 'mediating link' between them. An example of the RAT: base - snow - dance. The 'mediating' word is: ball. This makes: baseball, snowball and a ball is also a dance. The three words all have the same remote association with the fourth words. By using convergent thinking a participant can find the fourth word. For divergent thinking the AUT is used. In the AUT the goal is to generate as many as possible uses, different from the common use, for familiar objects (Gilhooly, Fioratou, Anthony, & Wynn, 2007). For example, a participant might be asked: *"What can you do with a brick"?* Possible answers are "building a house" but also "smashing in a window". The more creative and uncommon the answer, the more points the participant gets for the answer.

What influences creativity?

How creative someone is has been linked to dopaminergic levels of a person. Further research showed that the relationship between the level of dopamine and creative performances follows an inverted U-shape (Chermahini & Hommel, 2012; Colzato, Van Den Wildenberg, Van Wouwe, Pannebakker, & Hommel, 2009). This means that an average level of dopamine is linked to the best performances of creativity in terms of divergent thinking, whereas low or high levels of dopamine are linked to better performances in terms of convergent thinking. Medium levels of dopamine seem to improve cognitive flexibility, a quality linked to divergent thinking (Chermahini & Hommel, 2010; Chermahini & Hommel, 2012; Mayseless et al., 2013). Cognitive flexibility is the ability to switch between thinking about two different concepts, and to think about multiple concepts simultaneously. It has been shown to be a vital component of learning. Low or high levels of dopamine have the opposite effect, which is beneficial for convergent thinking. Furthermore, convergent thinking is positively correlated with intelligence. In their studies Chermahini and Hommel measured convergent creativity using the RAT, measured divergent creativity using the AUT, measured fluid intelligence using Raven's Progressive Matrices (RPM) and measured Eye Blink Rates (EBR) by using electrodes around the eye. Eye Blink Rate (EBR) is a well-established clinical marker (Shukla, 1985) to index striatal dopamine production (Karson, 1983; Taylor et al., 1999).

Creativity and gaming

In recent research a link has been found between creativity and gaming. Jackson et al.(2012) researched the relationship between children's information technology use and their creativity. They developed a multidimensional measure of creativity based on Torrance's Test of Creative Thinking (TTCT). The TTCT is a widely used test of measuring creativity. The test includes figural and verbal subtests and is oriented on four principal cognitive processes of creativity: (a) fluency or number of relevant responses; (b) flexibility as referred to a variety of categories or shifts in responses; (c) originality entails considering novelty responses, not familiar and unusual, but relevant; and (d) elaboration as referred to the number of details used to extend a response (Almeida, Prieto, Ferrando, Oliveira, & Ferrándiz, 2008). Jackson and colleagues had 491 children fill out questionnaires in order to determine their creativity. They found that all types of videogames were strongly related to all measures of creativity, except for racing/driving games. More play was associated with greater creativity. But it is important to point out that this research was a correlation study and therefore a cause-effect relationship could not be established. Still, there seems to be some link between gaming and creativity.

Playing videogames can have an effect on our cognitive abilities. In 2010, Colzato, van Leeuwen, van den Wildenberg and Hommel researched the effects of commercial First Person Shooters (FPS) on participants' cognitive abilities. They found that video-game players, compared to participants with little to no video-game experience, showed smaller switching costs on a task switching paradigm. They concluded that video-game players have a greater cognitive flexibility than no video-game players. In another study Oei & Patterson (2013) let participants play videogames for one hour a day, five days a week for over four weeks, consisting of different videogame genres. Oei and Patterson tested the participants on behavioural tasks before and after the training sessions for transfer effects. They found that the cognitive improvements were not limited to action game training alone and that different games enhanced different aspects of cognition. Furthermore they concluded that training specific cognitive abilities by frequently playing video games improved performance in tasks that share common underlying demands. However, they note that this may be due to near-transfer effects. However, Toril, Reales, and Ballesteros (2014) did a meta-analysis on twenty experimental studies between 1986 and 2013. The studies were video game training interventions with pre- and post-training measures. They found that video game training produced positive effect on several cognitive functions, including: reaction time, attention, memory and global cognition. Overall, playing video games seems to have an effect on our cognitive abilities. Furthermore, there is evidence for the release of dopamine in the brains of humans while playing video games (Koepp et al., 1998). It could be argued that since there is evidence for a link between gaming and increased creativity and there is evidence for a link between gaming and increased cognitive abilities, there might be a link between the change in cognitive abilities through gaming which lead to increased creativity.

Creativity and sport

Another aspect that has been linked to dopamine in quite some studies, just like creativity and gaming, is sport. For example, the amount of dopamine in the brains of rats increased after the rats exercised extensively (Meeusen & De Meirleir, 1995). So by exercising (i.e. sporting) the rats increased the amount of dopamine in their brain. Unfortunately, this effect has not yet been found in humans (Wang et al., 2000). But by giving people rewards their dopamine-level can also increase. And since sport can be very rewarding for people, sport might be able to have an influence on people's dopamine level. Other components of sport, next to rewarding, that can have an influence on dopamine are risk taking and pleasure (Pain, 2005).

But sports can also enhance a person's cognitive abilities. Voss, Kramer, Basak, Prakash and Roberts (2009) examined in a quantitative meta-analysis if the combination of fitness and cognitive training that results from years of extensive sport training also results in increased performance on tests of cognitive processes. They found that athletes performed better on cognitive tasks, such as measures of processing speed and attention paradigms. However, more research should be done to higher-level cognitive tasks. In 2013, Alves et al. investigated the relationship between sport expertise and perceptual and cognitive skills. They found that athletes showed superior performance speed on three tasks (two were executive control tasks and the other was a visuo-spatial attentional processing task). Alves et al. showed that even executive functions can improve by playing sports and that exercising can lead to a change in cognitive abilities, just like gaming can.

Current study

Creativity, gaming and sport all have one thing in common: dopamine. The relationship between these three is the main focus. We performed two studies to investigate this relationship. The first study was an observational study meant to research if videogame experience is positively related to convergent creativity and also explore the relationship between sport experience and creativity. Finally we will also research if cognitive flexibility can be enhanced by playing different videogame genres.

In the second study we wanted to do some explorative research into creativity. The goal of this study is that we wanted to investigate a causal link between videogame play and creativity by having people play games that specifically reward creative performance. Furthermore we wanted to see if people's EBR changed when having played creativity rewarding videogames for four weeks.

Experiment 1 - Sporting, Gaming and Creativity

In this observational study, firstly we wanted to research if videogame experience is related to convergent creativity, while additionally exploring if this relation depends on the type/genre of video games. We expect positive correlations for video game behaviour and the RAT scores, but not for the AUT, RPM or the Pasta-task.

Secondly, we wanted to investigate if a similar positive relation exists between sport experience and creativity. We expect positive correlations for sporting behaviour and the RAT scores, but not for the AUT, RPM or the Pasta-task.

Thirdly, we wanted to test if playing more video game genres (or games) result in people being more creative. We expect this to be the case because we believe there might be a link between playing different genres and cognitive flexibility. Cognitive flexibility is the switching between different concepts, which might also be the case when someone plays multiple genres. And since cognitive flexibility is linked to divergent thinking, we also expect people who play more video game genres (or games) to be more creative. We expect that people who play more genres (or games) to be more divergent thinking and therefore positive correlations on the scores of the AUT and the Pasta-task, but not for the RAT or the RPM.

Method

Participants

In this study 53 participants were tested. The participants were recruited from the Leiden University, by use of flyers, Facebook and the University's participant recruiting board. Participants received course credit upon completing the experiment. Participants filled in an online screening questionnaire, and if they met the criteria they were invited for the experiment. Participants were only selected for the follow-up test if they met a few criteria: they had to play video games for a minimum of one hour a week and no record of psychological illness (like ADD). Further they had to be at least 18 years old, have normal or corrected to-normal eyesight, no prior experience with creativity tasks and be native speakers of Dutch. After excluding participants based on these criteria, 33 (*M* = 24 yrs, 42% males) participants were invited for the follow-up test. The study has been reviewed and approved by the ethical committee of the University of Leiden. The study was conducted in accordance with the applicable laws and guidelines. Participants were able to quit without a specific reason at any time.

Design

The study is a between-subjects design, in which we will look for relationships between the number of videogame genres (games) played, hours of videogames played, years of playing at least one hour a week, hours sporting in a week, years of sporting and creativity. We will look for relationships between these variables by using regression. We chose regression because we wanted to analyze the relationship between two interval variables. The predictors are: the hours of videogames played, years of playing at least one hour a week, hours of sporting in a week, years of sporting and amount of genres (games) played. All independent variables are measured at interval level. The test sequence is counterbalanced between the participant to counterbalance for order effects. We have used a Latin square design. The questionnaire is always filled out after the tests. The dependent variable is the creativity score on the tests. This variable is categorized as interval. The score on the Remote Associations Task (RAT) is interval (how many did the participant correctly fill out), the Alternative Usage Task (AUT) is interval (how many suggestions did the participant give), Raven's Progressive Matrices (RPM) is interval (how many questions did the participant answer correctly) and the Pasta-task was interval (how many times did the subject switch between different endings of made up pasta names).

Procedure

First, participants were asked to fill out an online "lifestyle questionnaire", which was implemented to screen participants on certain behaviour. This "lifestyle questionnaire" took 15 minutes to complete. In order for participants to be invited to the follow-up study they had to fill out that they played videogames for at least one hour a week. To make sure the participants did not know that our interest was in gaming behaviour, the questionnaire consisted of a lot of different questions, ranging from musical experience to sporting experience and from electronical device usage to gaming experience.

Participants that played videogames for at least 1 hour a week received an e-mail with another online test and were asked to complete this test as well. This test consisted of four tasks, all to be completed after each other. The sequence in which the tasks were given to the participants was counterbalanced over the participants by using a Latin square design (Bradley, J. V., 1958) making sure no order effect could form a problem later on. The study consisted of the following tasks: The RAT (15 items, Mednick & Mednick, 1972), The AUT (2 items, Gilhooly, Fioratou, Anthony, & Wynn, 2007), The Pasta Task (Gocłowska, Baas, Crisp, & Dreu, 2014) and the RPM (Bilker et al., 2012). All tasks will be discussed in more detail in the 'scoring' section. The RAT, AUT and RPM all took ten minutes to complete. The Pasta task took five minutes After the tests participants were debriefed and the experiment ended.

Apparatus

Qualtrics software was used to make the online questionnaire (version 3.7.0 of Qualtrics. Copyright © 2017 Qualtrics. Qualtrics and all other Qualtrics product or service names are registered trademarks or trademarks of Qualtrics, Provo, UT, USA. http://www.qualtrics.com). All the participants' data of the questions and answers were recorded by Qualtrics for later analysis. Data recorded by Qualtrics was analyzed with SPSS (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.).

Tasks

RAT.

In the Remote Associations Task an examinee is presented with three words and is asked to supply a fourth word that is related to the other three. The three words are considered to be from 'remote associative clusters' and the fourth word is to provide a 'mediating link' between them (Mednick & Mednick, 1972). An example of the RAT: base - snow - dance. The 'mediating' word is: ball. Participants get one point for every word filled out correctly and this is measured at interval-level. The Remote Associations Task consisted of 15 items is linked to convergent thinking of creativity.

RPM.

The participants will also take a shortened version of the Raven's Progressive Matrices (RPM), a 60-item test to test for abstract reasoning, which is considered a nonverbal estimate of fluid intelligence (Bilker et al., 2012). In this experiment, Raven's Progressive Matrices will consist of 30 questions where participants have to identify the missing element that completes a pattern. The scoring on the RPM is at an interval-level, ranging from 0 to 30. The questions are ranked from easy to hard in a fixed pattern.

AUT.

In the Alternative Uses Task the goal is to generate as many as possible uses, different from the common use, for familiar objects (Gilhooly et al., 2007). For example, a participant might be asked: *"What can you do with a brick"?* Possible answers are "building a house" but also "smashing in a window". The more creative and uncommon the answer, the more points the examinee gets for the answer. This is linked to divergent thinking of creativity. Scoring is comprised of four components:

1) Originality: Each response it compared to the total amount of responses from all the people who took the test. Responses are unusual (one point) if they are only given by 5% of the total group. The response is unique when it is only given by 1% of the group (2 points). Higher scores indicate creativity.

2) Fluency: Total number of responses summed up.

3) Flexibility: In how many different categories can someone place the object (for example: a brick can be used as a weapon, but also as a building material).

4) Elaboration: How much detail is put into the response (For example: *a brick as a doorstop* is 0 points, but *a brick as a door stop to prevent a door from slamming shut because of strong wind* is 2 points, one for the explanation of door slamming and two for further detail about the strong wind).

Since we want to analyze divergent thinking by using the AUT, the main focus of this test is the component 'fluency'. Furthermore, we will sum up the scores of the two separate items into a single AUT score.

Pasta.

The Pasta tasks asks participants to come up with new types of pasta. The task also gives the participants some examples, like: spaghetti, fusili, ravioli. All examples given are types of pasta that end in "-i", which biases the participants into coming up with new pasta types that also end in "-i". The new types of pasta are scored on "fluency"(total number of responses), "flexibility"(how many different endings can someone come up with) and "switching" (switching between different endings), which are all measured at interval-level. The amount of switching a participant does when coming up with new pasta names has been linked to divergent thinking, a form of creativity (Gocłowska et al., 2014).

Questionnaire.

The questionnaire tries to uncover the participants video game, music and sport behaviour. For video gaming we asked participants what genre he or she plays, how often the participant plays, on what device (console, tablet, mobile phone) etc. Questions about other (digital) media (tv, radio, computer, smartphone) are included as well. For music we asked participants how often they listen to music, how long, what genre. For sport we asked how often participants sport, for how long, which sport they play, etc. The most important predictors for videogaming were: "How many hours a week do you play videogames", "how many games do you play in one month", "how many different genres do you play in one month", "how long is your average playing sessions (in minutes)" and "for how many years have you been playing videogames for at least one hour a week". The most important predictors for sporting were: "How long have you been sporting (in years)", "at what age did you start sporting" and "how many hours do you sport on average per week".

Analysis

The scores on the creativity tasks are the dependent variables, whereas the gaming and sport experience are the independent (predictor) variables. Regression-models will be used to analyse the data. First we tested our predictions using Pearson correlation (or Spearman in case of data that are not normally distributed). Significance was tested at alpha >= .05. We predicted a positive correlation between "hours gaming", "years of playing one hour a week" and scores on the RAT, between "hours sporting", "years of sporting" and scores on the RAT and finally between "number of genres", "number of games" and the scores on the different tests. Secondly, we performed an explorative stepwise backwards regression analysis for each task, including as predictors all the variables concerning gaming and sports. All variables that were analyzed with this explorative backwards regression can be found in the Appendix. We will describe the model with the least amount of predictors. The assumptions we tested were: Normality, Variability (Levene's) and Sphericity (Mauchly's).

Results

Sample Descriptives

The 33 participants (*M* = 24 yrs, 42% males) played videogames for 2.15 hours (*SD* = 2.31) a week on average. Furthermore, they played close to 2 different games a month (*M* = 1.93, *SD* = 1.19) and close to 2 different genres (*M* = 1.84, *SD* = 0.94). The average length of their playing sessions was 53 minutes (*M* = 52.73, *SD* = 36.03) and they have been playing videogames for at least one hour a week for 10 years (*M* = 10.00, *SD* = 5.90). Participants have been sporting even longer, with an average of 16.64 years (*SD* = 3.35). They started sporting at the age of 5.5 (*SD* = 1.50) and sport 5.80 hours (*SD* = 4.34) a week on average. All other variables and their statistics can be found in Table 1.

Table 1.
Means and Standard Deviations of All Variables

Variable	***M***	***SD***
Avg. hours of videogaming per week	2.15	2.31
Avg. hours on a console	1.55	2.31
Avg. hours on a computer	1.85	4.02
Avg. hours on a smartphone	3.52	10.39
Avg. hours on a tablet	0.39	1.09
Avg. playing-session length	52.73	36.04
Number of games a month	1.94	1.20
Number of genres a month	1.85	0.94
Number of years of gaming at least one hour a week	10.00	5.90
Avg. hours a week playing RPGs	0.06	0.35
Avg. hours a week playing Shooters	0.72	1.57
Avg. hours a week playing RTS	0.21	0.70
Avg. hours a week playing Adventure games	0.24	0.79
Avg. hours a week playing Simpel games	1.55	3.58
Avg. hours a week playing MMOs	0.30	1.43
Avg. hours a week playing Sport games	0.73	1.99
Avg. hours a week playing Simulations	0.39	0.75
Avg. hours a week playing Puzzel games	0.30	0.95
Avg. hours a week playing Classic games	0.03	0.17
Avg. hours a week playing Braintraining games	0.06	0.24
Avg. hours a week playing Other games	0.27	1.10
Years of sporting	16.64	3.35
At what age did you start sporting	5.50	1.50
Avg. hours of sporting in one week	5.80	4.35

All predictors have been tested on normality by using the Shapiro-Wilk test. The predictors "hours videogaming a week", "years playing videogames at least one hour a week", "playing sessions lenght" and "years of sporting" were normally distributed, all $p >$ .060. The other predictors were not normally distributed, $p <$ .048, and we will use Spearman's correlation for these predictors, instead of Pearson's. However, when looking at the Q-Q plots for the non-normally distributed predictors, some predictors do seem to be normally distributed.

Task Descriptives

Non of the task scores were normally distributed according to Shapiro Wilk statistics, all $p >$ .042. This means we will use Spearman's correlation instead of Pearson's. However, when looking at the Q-Q plots, the scores on the Raven's Progressive Matrices looked to be normally distributed.

Participants correctly answered 7.66 items out of 15 (SD = 0.39) on average on the Remote Associations Task (RAT), with a range between 0 - 11 items. On the Alternative Usage Task (AUT) participants came up with 22.31 items (SD = 3.08), with a range between 6 - 80 items. On the Pasta-task participants came up with 9.94 items (SD =1.23), with a range between 1-33. The correct number of items on the Raven's Progressive Matrices (RPM) was 26.25 out of 30 (SD = 0.32) on average, with a range between 23-29.

Before testing our predictions, we first conducted a correlation between the different tests. We expect that the AUT and the Pasta-task measure the same kind of creativity (i.e. divergent). In line with our prediction, there was a significant positive Spearman's correlation between the fluency components of the AUT and the Pasta task, $r_s = 0.417$, $p =$ .018. Both tests seem to measure the same component of creativity. Furthermore, the RAT is not significantly correlated to either the AUT or the Pasta-task, which was also in line with our predictions.

Videogame Effects

In contract to our first hypothesis, there was no significant correlation between 'hours gaming' and convergent thinking (RAT scores), nor between 'year playing' and RAT scores, see Table 2. However, there is a significant positive correlation between the score on the RPM and 'years playing', explaining 16.9% of the total variance, $r = 0.412$, $p =$ .033. This is not in line with our predictions.

Table 2.
Pearson's correlations Between Variables and Tests

Independent		**RAT**	**AUT**	**Pasta**	**RPM**
hours gaming					
	r	-0.247	0.244	-0.115	-0.067
	p	0.224[1]	0.23	0.575	0.746
years playing at least one hour a week					
	r	0.227	0.262	0.225	0.412
	p	0.255	0.186	0.27	0.033*

Sport Effects

In contract to our hypothesis, there was no significant correlation between 'hours sporting' and convergent thinking (RAT scores), nor between 'years sporting' and RAT scores, see Table 3. However, there is a significant positive correlation between the score on the AUT and 'years sporting', explaining 20.6% of the total variance, $r = 0.454$, $p = .015$. This is not in line with our predictions.

Table 3.
Correlations between Variables and Tests

Independent		**RAT**	**AUT**	**Pasta**	**RPM**
hours sporting					
	Spearman's rho	0.102	-0.19	-0.121	-0.033
	p	0.606	0.332	0.547	0.869
years sporting					
	Pearson's r	0.02	0.454	-0.034	0.243
	p	0.919	0.015*	0.865	0.212

Videogame Genre Effects

Thirdly, we will test if playing more videogame genres (or games) results in people being more creative. We will test this hypothesis by computing the correlations between the amount of videogame genres people play and the scores on the different tests. Furthermore we will also look at the relation between how many different games a month a participant plays and his/her scores.

[1] We tested if the relationship could be something else than linear. But after correction for outliers, the quadratic regression analysis failed to reach significance.

Table 4.
Spearman's Correlations Between Variables and Tests

Independent		**RAT**	**AUT**	**Pasta**	**RPM**
How many different genres do you play per month					
	rho	0.054	0.263	-0.017	0.208
	P	0.767	0.139	0.926	0.244
How many different games do you play per month					
	rho	0.069	0.098	-0.059	0.082
	P	0.701	0.588	0.747	0.65

As can be seen from Table 4, there were no significant correlations between either the amount of genres or the amount of games a participant plays per month and the scores on the tests[2].

Backwards regression

To further explore which predictors do have an effect on the scores of the different tests, we also conducted a backwards stepwise regression as an explorative analysis. For the scores on the RAT, the regression model containing only the predictor 'How many hours a week do you play shooters?', explained a significant proportion of the variance 13,5%, F (1, 30) = 4.67, p = .039. The predictor has a significant negative coefficient B = -0.367, which means that playing shooters more hours a week results in lower scores on the RAT.

For the scores on the AUT the latest regression model, containing six predictors, explained a significant proportion of the variance 46.9%, F (6, 25) = 3.684, p = .009. As can be seen in Table 5, the first predictor ('how many hours a week do you play games on the computer') and the second predictor ('how many hours a week do you play games on the tablet') were negatively related to AUT scores. The third predictor ('how many hours a week do you play role playing games'), the fourth predictor ('how many hours a week do you play simple games'), the fifth predictor ('how many hours a week do you play online games with a lot of other people (MMO's)') and the sixth predictor ('how many hours a week do you play sport games') were all positively related to the AUT scores.

[2] We conducted a Bonferroni correction to control for inflation of the Type I error. There were no significant correlations left after the correction.

Table 5.
Summary of Model's Predictors and Statistics

Predictor	*B*	*p*
hours playing on computer'	-1.259	.003
hours playing on tablet'	-0.411	.026
hours playing RPGs'	0.364	.022
hours playing simple games'	1.275	.002
hours playing MMOs'	0.615	.009
hours playing sport games'	0.828	<.001

For the Pasta Fluency Task the latest regression model, containing four predictors, explained a significant proportion of the variance 39,6%, F (4, 26) = 4.255, p = .009. As can be seen in Table 6, the first predictor ('how many hours a week do you play games on your smartphone') and second predictor ('how many hours a week do you play games on your tablet') were negatively related with scores on the Pasta Fluency Task. The third predictor ('how many hours a week do you play simple games') and the fourth predictor ('how many hours a week do you play other genres') are positively related to scores on the Pasta Fluency Task.

Table 6.
Summary of Model's Predictors and Statistics

Predictor	*B*	*p*
hours playing on smartphone'	-1.787	<.001
hours playing on tablet'	-0.456	.026
hours playing simple games'	0.976	<.001
hours playing other genres'	0.449	.014

Finally for the RPM, the latest regression model, containing two predictors, explained a significant proportion of the variance 21,1%, F (2, 29) = 3.868, p = .032. The first predictor 'how many hours a week do you play on the tablet' has a significant negative coefficient, B = -0.339, p = .050. The second predictor 'how many hours a week do you play online games with a lot of other people (MMO's)' had a non-significant positive coefficient, B = 0.286, p = .094.

Discussion

The aim of the study was exploring the relationship between creativity, gaming and sport. We wanted to research the relationship between videogame experience and convergent creativity, while additionally exploring if this relation depends on the type/genre of video games. Furthermore we investigated if a similar relation exists between sport experience and convergent creativity. Finally we also looked if playing more videogame genres (or games) resulted in people being more creative.

Unlike our first prediction, we did not find any relation between 'hours gaming' or 'years playing' and convergent thinking. A possible explanation could be that the hours of gaming per week was too low to expect better scores on the convergent thinking task. Research by Lorenz, Gleich, Gallinat and Kühn (2015) showed that playing videogames can keep striatal responses to rewards flexible. With this finding in mind, we should expect that videogames keep their rewarding nature, leading to higher dopaminergic levels in gamers. As noted before (Chermahini & Hommel, 2010), higher levels of dopamine seem to increase performance on convergent tasks. That is why we expected better scores on the RAT for people who game a lot. But with an average of only 2 hours of gaming a week in this sample, this effect may have failed to be realized. However, we did find that more years of gaming experience was associated with higher scores on Raven's Progressive Matrices (RPM). Research showed that playing videogames can have beneficial effects on cognitive abilities, such as cognitive switching, memory, attention and global cognition (Toris, Reales & Ballesteros, 2014). This could be an explanation for the fact that people who have been playing games for a long period of time tend to have higher scores on the RPM. Although, we should expect the predictor 'how many hours a week do you play games' to be correlated as well, but this is not the case. A possible explanation could be that the effects of gaming on cognition become visible over a longer period of time (years) and not so much transfer immediately. This is something that should be researched further over time. Another (more simple) explanation could be that university students have less time to spend on gaming than they had when they were on high school. This way they score high on 'years of gaming experience' but may score low on 'hours gaming' since they are too busy with school. This could explain why 'year gaming' was associated with higher RPM scores, but the predictor 'hours gaming' was not.

As for our second prediction, we did not find any relation between 'hours sporting' or 'years sporting' and convergent thinking. A possible explanation could be that dopaminergic levels in sport are only higher in individuals who are risk-taking and seeking rewards. More than half of our sample exercised only for recreation, which might explain why we failed to find any relation between sport and convergent thinking. However, we did find that the predictor 'years sporting' was associated with higher scores on the Alternative Usage Task (AUT). Since more than half of our sample only exercised for recreation, they may not experience changes in dopamine levels caused by rewards and risk-taking. This means their level would be more around average, which explain the higher scores on the AUT (Chermahini and Hommel, 2010). Another possible explanation could be that sporting for years may have regulated the dopamine level in these participants. Meaning that instead of high or low levels of dopamine, they have medium levels of dopamine when they are in rest (which they were during the testing). This can explain why they came up with more items on the AUT. A way to research this further is to take a larger sample and to split up recreational and competitive athletes to see if there is indeed a difference in dopaminergic levels.

In contrast to the third hypothesis, we did not find a relation between participants becoming more creative when playing more genres or games. Previous research by Jackson et al. (2012) found that people who play different kinds of videogame genres tend to be more creative when compared to people who only play one genre. A possible explanation could be that our sample size was a lot smaller than the sample size Jackson et al. used (33 participants versus 491) and therefore we failed to replicate this finding. Another difference is that the sample of Jackson and colleagues consisted of young children (with an average age of 12 years), while our sample consisted of adolescents (with an average age of 24). Finally, Jackson et al. tested creativity using the Torrance's Test of Creative Thinking (TTCT), where we tested creativity using the AUT. The TTCT measures different components, such as fluency, flexibility, originality and elaboration. At the AUT, we only looked at the fluency component, since we were looking into divergent thinking. It could be possible we would have found a relationship if we also checked for the other components. Yeh (2015) found that creative performances after playing action games were more original, flexible and elaborated than ideas generated after playing non-action games. This argues that in further research all components should be looked into, not just fluency.

Using backwards regression we explored whether the task scores could be predicted by any combination of the variables. One particular finding was interesting: For the RAT, playing shooters was more often associated with lower RAT scores. This is in line with previous research by Colzato, van Leeuwen, van den Wildenberg and Hommel (2010). They found that players of First Person Shooters had smaller switching costs (i.e. they had greater cognitive flexibility). In the RAT participants are engaged to convergent thinking and actively try to find the associated word. Greater cognitive flexibility could impair participants in finding the associated word. Thus, our finding that the predictor 'how many hours a week do you play shooters' is negatively correlated to RAT scores is in line with previous research. However, our sample is limited in size and further research is required to draw a strong conclusion.

As noted before, a limitation of our research is the sample size. After correcting for the inflation of the type I error by using Bonferroni there were no significant results left. This could be caused by our small sample size, which failed to reach enough power. With only thirty-three participants it is already hard to get significant results and if we find something the conclusions that can be based on the results are not that strong. Furthermore, with a larger sample size we might have found some effects we did not find in this analysis because of the lack of power. A larger sample size would also have helped with a more normal distribution among the participants. For further research a larger sample size is needed.

Experiment 2 - The pilot study

In our second (pilot) study we wanted to do some explorative research into creativity. We only chose participants that played games for at least one hour a week, since there is evidence that having experience with gaming can lead to different results, compared to people without any gaming experience (Colzato, van Leeuwen, van den Wildenberg & Hommel, 2010). The goal of this study is that we wanted to investigate a causal link between videogame play and creativity by having people play games that specifically reward creative performance. We chose games that required participants to think creatively in order to solve puzzles. These games gave positive feedback to the participants when they completed puzzles. By rewarding people's creativity we expect people to get higher amounts of dopamine, because rewards can increase someone's dopamine. We expect participants in the experimental intervention (who played creativity rewarding games) to significantly improve on their post-intervention scores, compared to people in the active (who played music games) or the passive (no contact) control group, because higher dopamine levels are correlated with convergent thinking, a form of creativity. Furthermore we wanted to see if people's EBR changed when having played creativity rewarding videogames for four weeks. We expect a significant change in Eye Blink Rate (EBR) in the experimental group, when compared to the active and passive control group. Dopamine can be a possible mediator, because the level of dopamine is tied to creativity as well as rewards. Rewards could increase dopamine which in turn could increase creativity (or the other way around). Since we have not tested a representative sample, all results that are reported in this study should be considered preliminary results.

Method

Participants

In this study 14 participants (*M* = 35 yrs, 44% males) have been tested. The participants were recruited from the Leiden University, by use of flyers, Facebook and the University's participant recruiting board. Participants received course credit upon completing the experiment. Upon completing the experiment the participant received 16 credits (or 8 and the chance to win a tablet) or 4 (when participating in the no contact control group). Participants were only selected if they met a few criteria: they had to be at least 18 years old, have normal or corrected to-normal eyesight, no prior experience with creativity tasks, native speakers of Dutch, no record of psychological illness (like ADD) and have access to a smartphone and corresponding application store. Further The study has been reviewed and approved by the ethical committee of the University of Leiden. The study was conducted in accordance with the applicable laws and guidelines. Participants were able to quit without a specific reason at any time

Design

The study is a mixed-design, in which we compare the pre-test with the post-test (within subject) of both the experimental and the control condition (between subjects). In the pre- and post-test we test participants on a number of tasks which measure creativity (Remote Associations Task, RAT, and Alternative Usage Task, AUT) and fluid intelligence (Raven's Progressive Matrices, RPM). By comparing pre- to post-test we can see if participants improved, scored worse or scored equally well after our intervention. Furthermore, we also look at the difference between the experimental and control groups. The type of videogame is the independent variable and is measured on a categorical level. Participants were divided over four groups: music games (with sound), music games (without sound), creativity rewarding games or a no contact control group (these people did not play games). The different interventions have different effects on the creativity level of the participants. We counterbalanced the different conditions among the participants. Also the version of the tests was counterbalanced among the participants. The creativity-scores on the different tests are all measured at interval-level.

Procedure

First, participants willing to take part in the experiment will be screened on their gaming and multimedia behaviour, since there is evidence that having previous experience with gaming can lead to different results (Colzato, van Leeuwen, van den Wildenberg &

Hommel, 2010). Participants that had the right criteria were be invited for an intake of the experiment. In the pre-test participants will fill out questionnaires and take three tests. The participants are tested on their convergent thinking skills with the Remote Associations Task and on their divergent thinking skills with the Alternative Uses Task. The last test will be Raven's Standard Progressive Matrices, testing for the ability of abstract reasoning. During testing the eye blink rates of the participants were measured, to determine their level of dopamine. The eye blinks rates of participants were measured by using a webcam to film the participants. Later these videos could be scanned by eye blink detection software, which would provide information about the average eye blink duration and the average amount of eye blinks per minute. After the testing, participants were randomly assigned to one of the four training interventions, which are: Music games without sound, music games with sound, creativity-rewarding games and a no-contact control group. Participants completed the training intervention on their own. Each training intervention consisted of 20 training sessions in a total of 4 weeks, 5 times a week, 30 minutes per session (for a total of 10 hours of training). After the 4 weeks of training intervention the participants returned once more to the lab for a post-test, consisting of the same tests (RAT, AUT, RPM), measurements (EBR) and questionnaires as they did at the pre-test. Afterwards the participants are debriefed and given course credit upon completing the experiment.

Materials

For the training intervention the following mobile applications have been chosen: *Piano Tiles 2, Beat Stomper, Geometry Dash Lite, Beats (Advanced Rhythm Game), Scribblenauts remix, Brain it on the truck!, 100 floors* and *Unblock me (free)*. Piano Tiles 2, Beat Stomper, Geometry Dash Lite and Beats (Advanced Rhythm Game) are all games based on music or musical components and therefore those games will be played by participants in the musical part of the training intervention. Scribblenauts remix, Brain it on the truck!, 100 floors and Unblock me (free) are all games based on creativity, divergent or convergent, and therefore those games will be played by participants that are part of the creativity intervention. The no-control group will not play any games at all. Since this research focuses on the link between creativity and playing creativity rewarding games, only further information will be given on the games played in the creativity intervention:

Scribblenauts remix focuses on the player's imagination and divergent thinking. Players get objectives and can think of anything to complete the task at hand. This requires convergent thinking as well, but the more creative a player is (divergent thinking), the more points he will be rewarded. The only limit is the player's own imagination.

Brain it on the truck! is a physics puzzle game, where players have to move a certain object to a certain area. To do this they can use a truck, a crayon and their imagination. Any design that players draw become physical objects that can interact to physical objects in the game.

100 Floors is a game consisting of 100 levels where the player needs to open the elevator door on each floor in order to continue to the next level. All floors are puzzles and it is up to the player to figure out how to open the elevator door on that specific floor, since all floors are different.

Unblock me (free) is a puzzle game where players need to move blocks around in a square to make room for one specific block. That block has to be lead to the exit, but since the other blocks are blocking the path they need to be rearranged first.

The pre- and post-test consisted of three tests: the Remote Associations Task, The Alternative Uses Task and Raven's Progressive Matrices (Bilker et al., 2012). The tests were set up in the same way as in experiment 1, but now the participants did each test twice (once in the pre-test and once in the post-test).

Scoring

To make sure all the participants are actually playing the game, participants are asked to send a pre-training screenshot and a post-training screenshot of their mobile phone. To keep track of this an Excel-sheet has been made, where it was registered when a participant sent a screenshot. This Excel-sheet also keeps track of the dates when a reminder has to be send to the participants, when their post-test is due, their contact information (on a different page to secure its anonymity), and their training progress.

In this study we looked at the difference in scores between the pre- and post-test on the RAT and the RPM, as well as the fluency on the AUT. Eye blink rate was measured by filming the participants with a webcam. Later these videos were analyzed using eye blink detection software, which provided us with the average amount of eye blinks per minute and the average duration of the blinks.

Analysis

The study is a mixed design, analyzing between groups and within subject patterns. The scores on the creativity tasks are the dependent variables, whereas the different interventions are the independent (predictor) variables. All tasks were measured at an interval-level. The score on the RAT is interval (how many did the subject correctly fill out), the AUT Fluency component is interval (how much can a participant come up with), RPM is measured at interval level (how many questions did the participants answer correctly) and so is the Pasta Task (how many times did the subject switch between different endings of made up pasta names). The assumptions we tested were: Normality, Variability (Levene's) and Sphericity (Mauchly's).

Results

Does playing creativity rewarding games enhance people's convergent creativity? We tested this by comparing pre-intervention scores to post-intervention scores of participants. We expected participants in the experimental intervention (who played creativity rewarding games) to significantly improve on their post-intervention scores, compared to people in the active (who played music games) or the passive (no contact) control group.

First we will discuss some violations of the assumptions we tested. All data were distributed normally, except for the data from the Alternative Usage Task (AUT). For variability, all Levene's tests were significant.

Sample Descriptives

Before going into detail we will start by giving some general descriptives of the tests and the groups. There were four people in the no music group, four in the music group, three in the creativity group and three in the no contact group. On the Remote Associations Task (RAT) the participants scored an average of 6.08 items (*SD* = 2.78) out of 15 on the pre-test, while they scored 5.83 items (*SD* = 2.86) items on average on the post-test. On the AUT the participants came up with 21.83 items (*SD* = 12.69) on the pre-test, while on the post-test they came up with 22.83 (*SD* = 14.51) items on average. And participants correctly answered 25.20 (*SD* = 2.66) out of 30 items on the Raven's Progressive Matrices (RPM) on the pre-test, while they correctly answered 22.10 (*SD* = 3.35) items on the post-test.

Table 7.
ANOVA Table of the Tests

		df	*F*	*p*	η^2
Session	RAT	1.000	1.286	.300	0.176
	AUT	1.000	0.012	.915	0.002
	RPM	1.000	7.293	.036*	0.549

Group	RAT	3.000	1.860	.237	0.482
	AUT	3.000	0.939	.471	0.287
	RPM	3.000	1.987	.217	0.498
Group x Session	RAT	3.000	8.000	.016*	0.800
	AUT	3.000	0.502	.693	0.177
	RPM	3.000	0.699	.586	0.259

Behavioural Effects

As can be seen from Table 7, there was no main effect of session nor of condition on the RAT, but there was a significant interaction effect, $F(3, 6) = 8.000$, $p = .016$, $\eta^2 = 0.8$. This means that the difference between scores on the RAT depend on which group you are in. To further test which groups differ significantly from each other, we have conducted an univariate ANOVA with a post-hoc Bonferroni test. This test showed that there was a significant difference (p = .022) between the interventions "creativity rewarding" and "music". This finding is in line with our prediction: participants in the experimental condition scored higher on the RAT (a convergent thinking task) than the control group.

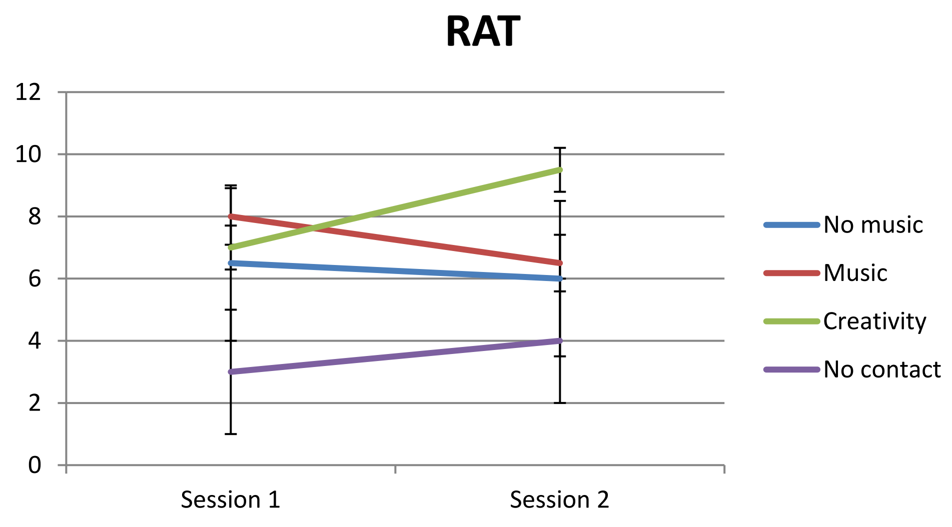

Figure 1. Interaction effect on the RAT

As can be seen in Table 7, for the AUT there was no main effect of session nor was there a main effect of condition. There was no interaction effect as well. Scores in the AUT did not significantly differ from each other over session or between conditions. This is in line with our prediction.

Finally, for the RPM there is a main effect of session, $F(1, 6) = 7.293$, $p = .036$. Such that participants on average scored higher on the post-test session ($M = 25.2$, $SD = 2.66$) than on the pre-test session ($M = 22.1$, $SD = 3.35$). There was no main effect of condition, nor was there an interaction effect.

EBR Effects

Does someone's eye blink rate (i.e. amount and rate) change when having played creativity games for 4 weeks? We expect a significant change in eye blink rate in the experimental group, when compared to the active and passive control group.

First we will discuss violations of the assumptions we tested. We have tested for the same assumptions as we did for the previous hypothesis. The only violation was that the eye blink duration data from the post-test was not normally distributed.

Participants on average blinked 12.35 ($SD = 9.27$) times a minute in the pre-test, while this average was 12.48 ($SD = 6.64$) at the post-test. For eye blink duration, the average was 0.18 seconds ($SD = 0.12$) on the pre-test and 0.21 seconds ($SD = 0.15$) on the post-test.

Table 8.
ANOVA Table of the Eye Blink Rate

		df	*F*	*p*	η^2
Session	Eyeblink amount	1	2.604	.167	0.342
	Eyeblink duration	1	12.013	.013*	0.667
Group	Eyeblink amount	3	0.585	.646	0.226
	Eyeblink duration	3	1.114	.414	0.358
Group x Session	Eyeblink amount	3	4.947	.046*	0.712
	Eyeblink duration	3	33.736	<.001*	0.944

Eye Blinks.

As can be seen from Table 8, we found no main effect for session and nor did we find a main effect for condition for the amount of eye blinks. However we did find an interaction effect, $F(3, 6) = 4.947$, $p = .046$, $\eta^2 = 0.712$. This means that the difference of amount of eye blinks between sessions depends on which condition you were in.

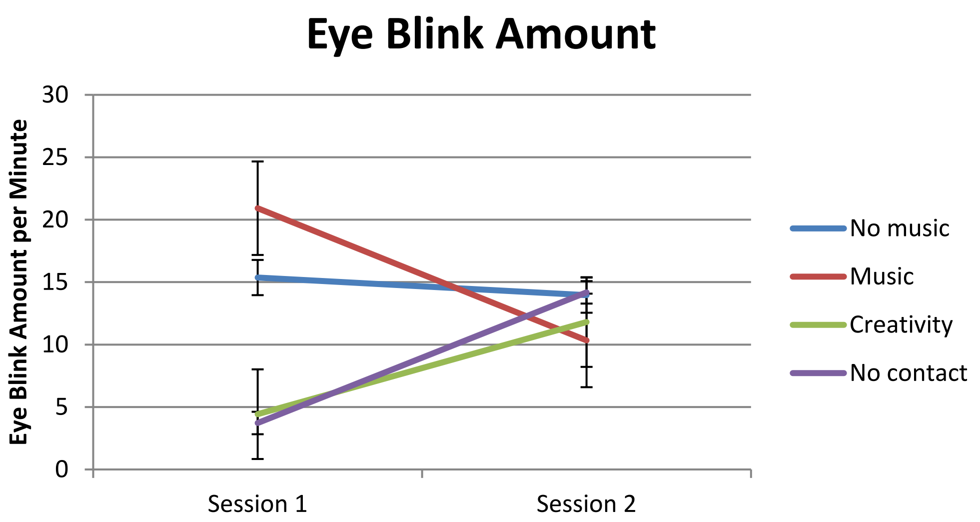

Figure 2. Interaction effect of eye blink amount.

But when we calculated the difference between sessions and analyzed this with a univariate ANOVA and a post-hoc Bonferroni test, there was no significant difference between any of the conditions. To further investigate this we repeated the repeated measures ANOVA, but now we added the first session as covariate. In this analysis the interaction effect disappeared, $F(3, 5) = 1.312$, $p = 0.368$. This means the significant interaction we found may be caused by other factors, which we will further discuss in the discussion.

Eye Blink Duration.

As can be seen from Table 8, there is a main effect on session, $F(1, 6) = 12.013$, $p = .013$, for duration of eye blinks. This means that there is a significant difference between the average eye blinks duration on the different sessions, such that the duration of eye blinks during the pre-test (M =0.18 , SD = 0.12) was shorter than the duration during the post-test (M = 0.21, SD = 0.15). There was no main effect of condition. However, there was a highly significant interaction effect, $F(3, 6) = 33.736$, $p < .001$, which is in line with our prediction.

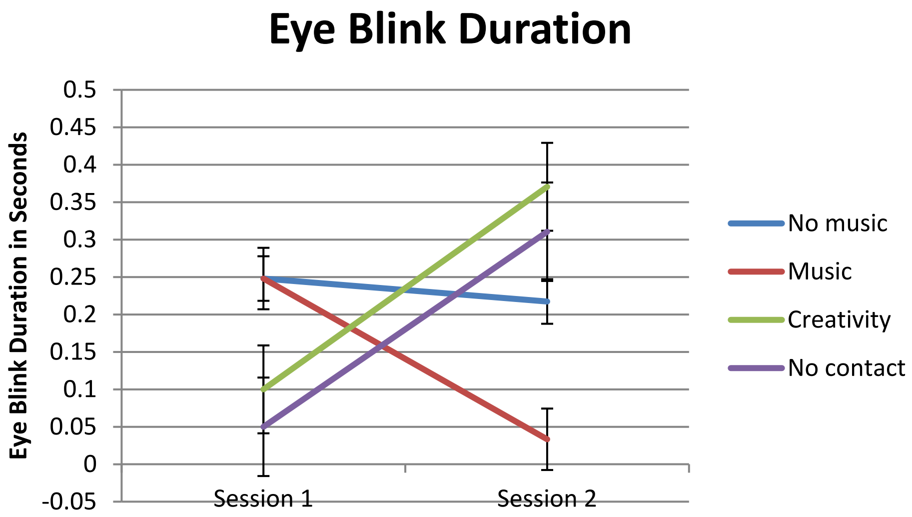

Figure 3. Interaction effect of eye blink duration.

Figure 3 shows us this interaction effect. The interaction effect here means that the difference in eye blinks durations between the sessions depend on which intervention you were placed in. A post-hoc Bonferroni corrected ANOVA been conducted to see which interventions differ significantly; no music and creativity rewarding (p = .012), no music and no contact (p = .015), music and creativity (p = .001) and music and no contact (p = .001). The participants in the creativity and no contact group seem to significantly increase their blink duration in the second session, while the participants in the no music or music intervention seem to blink shorter in the post-test. This finding is in line with our prediction.

Discussion

The aim of the study was to explore if people get more creative when they play creativity rewarding games. We wanted to compare creativity rewarding gamers against a control group, who played music games or no games at all. Furthermore, we wanted to see if the eye blinks rates of these creativity gamers change after a period of four weeks.

For the Remote Associations Task (RAT) we found that the creativity rewarding intervention led to greater improvement in scores as compared to the music intervention. Participants in the creativity rewarding group should have higher dopamine levels, because of the four week intervention. Indeed they scored higher on the Eye Blink Rate (EBR) than the music intervention. Additionally to the increased EBR, the creativity intervention also led to improved scores on the RAT, a convergent thinking task where people with high dopamine levels excel (Chermahini & Hommel, 2010), which is in line with our prediction. For the AUT we did not find any effect, something that is in line with our predictions. On the Raven's Progressive Matrices (RPM) there was a main effect of session. Participants scored higher on the post-test session than on the pre-test session. This could be due to a learning effect, since the same items were used in the post-test as in the pre-test.

Finally we expected a change in eye blink rate (duration and amount) in the experimental group, when compared to the active and passive control group. For the amount of eye blinks we found an interaction effect. However, when analyzing this interaction effect with a post-hoc Bonferroni test, it disappeared. After correction there were no groups that differed significantly from each other. When you look at figure 2, the groups have a wide range in amount of blinks in session one, whereas in session two they are all close to each other. This could be due to regression to the mean. This can happen when there is an unfortunate difference in the pre-test which disappears in the post-test. This difference is likely caused by our small group sample. This is something for further research with a larger pool of participants.

For eye blink duration we found that participants in the creativity and no contact group increase their blink duration in the second session, while participants in the music or no music group blinked shorter in the second session. So groups that started with high eye blink durations in the first session, ended up the lowest in the second session. It is in line with our predictions that people who were in the creativity rewarding intervention have a higher eye blink rate because they have had an intervention for four weeks. Their dopamine level should be higher in the second session than in the first, which results in a higher eye blink rate. Although, the no contact control group improved as well, with no intervention at all. This is an interesting finding. But when we look at the data, we see that there are only three people in the no music condition, and that for two out of the three people the data for the first session are missing. There was some trouble with the software not always supporting the videofile and therefore we were unable to use the eye blink detection software correctly on all videos, since some of the videos were 'corrupted'. This limits our research and should be taken into account for further research.

Another possible limitation is our subject pool. With only 14 participants it is hard to draw any conclusions. And adding the missing data because the eye blink detection software and the recording software were not always in sync, it becomes almost impossible to draw any conclusion at all. But what we have tried to do here is to do an exploratory pilot for future research. With a larger sample pool to correct for corrupted videos and to add more power, a promising result is likely to be acquired.

General Discussion

The main focus of this study was the relationship between creativity, gaming and sport. Our main goal of our experimental observational study was to research the relationship between videogame experience and convergent creativity, while exploring if this relation depends on type/genre of video games. We did not succeed in finding such relation. A possible explanation could be the low amount of hours the participants played on average, which meant they did not experience higher dopaminergic levels and did not perform better on convergent thinking tasks (Chermahini & Hommel, 2010). We did find a relation between years of gaming and higher scores on Raven's Progressive Matrices (RPM). This is in line with previous research (Toris, Reales & Ballesteros, 2014) which showed that playing videogames can have beneficial effects on cognitive abilities.

Secondly, we investigated if a similar relation exists between sport and creativity. We found no such relation. A possible explanation could be that we failed such relation because half of our sample exercised only for the pleasure of recreation. This could have had a different effect than people that sport for competition, meaning no risk-taking or reward seeking behaviour. This may have affected their dopaminergic levels, which led to no increase in their convergent thinking skills. We did find that 'years sporting' was associated with higher Alternative Usage Task (AUT) scores. This is in accordance with not finding the increase in convergent thinking. Sport may have various effects on dopaminergic levels.

Thirdly, we wanted to test if playing more video game genres (or games) result in people being more creative. We did not find this relation. However, previous research (Jackson et al., 2012) did find this relation. This difference could be due to the sample size (33 versus 491) and their age (24 versus 12). Also, we only tested the fluency component of the AUT, where Jackson et al. used the Torrence Test of Creative Thinking (TTCT). The TTCT consists of multiple components, such as fluency, flexibility, originality and elaboration. Yeh (2015) also found better creative ideas (more original, flexible and elaborated) after participants played action games than the ideas that were generated after playing non-action games. It could be possible we would have found a relationship if we also checked for other components. This is something for further research.

Finally, in our observational study we used backwards regression to explore whether the task scores could be predicted by any combination of the variables. One particular finding was interesting: For the Remote Associations Task (RAT), playing shooters was more often associated with lower RAT scores. This is in line with previous research by Colzato, van Leeuwen, van den Wildenberg and Hommel (2010). They found that players of shooters had greater cognitive flexibility. Greater cognitive flexibility could impair convergent thinking, thus be negatively correlated to RAT scores.

In our pilot study we wanted to investigate a causal link between videogame play and convergent creativity by having people play games that specifically reward creative performance. We indeed found that people in the creativity reward group scored better on the RAT in the second session. This was in line with our predictions. Furthermore, we also explored if people's Eye Blink Rate (EBR) changed when having played creativity rewarding videogames for four weeks. There was an interaction effect in line with our predictions. Participants in the creativity rewarding group indeed had a higher EBR in the second session. Both findings are in line with previous research by Chermahini and Hommel (2010), who found that low or high measures of EBR are linked to increased performance on convergent thinking tasks, whereas average measures of EBR are linked to increased performance on divergent tasks. EBR has been proven to be a well-established clinical marker (Shukla, 1985) to index striatal dopamine production (Karson, 1983; Taylor et al., 1999). Although, it is interesting that in the pilot study we found that people who play creativity rewarding videogames are indeed scoring better on the RAT, possible due to a higher level of dopamine. But in the observational study we did not find that people who game more are indeed better on the RAT. It could be that video gaming alone is not enough, since the music- and no music group-intervention in the pilot did not improve as well, but they have been playing videogames for four weeks. Giving people explicit rewards and positive feedback might be important when trying to raise someone's dopamine level, instead of just gaming. This is something that should be researched further, with more participants and in the settings of the experimental study. Giving people positive feedback before the RAT may cause people to score differently.

It is important that we do further research into the topic of enhancing creativity, by means of gaming or sporting. We have explored the possibility to enhance creativity (i.e. convergent creativity) by gaming, but further research will be needed to make solid claims. There are several studies who find promising results (such as Chermahini and Hommel, 2010, or Jackson et al., 2012) but there are also studies who do not believe in these effects (Boot, Blakely & Simons, 2011). It is important that we do more research on the topic of how creativity, gaming and cognition are connected so that we can form a solid theoretical ground. It is needed to get a more closer look, instead of a general theory in which no one knows which variable influences what. From a more practical point of view we have seen that gaming can have a positive effect on cognitive abilities and that it can even influence creativity in some way. But if we can establish a well-based causal link between gaming and creativity we can learn more about the brain as a whole and how to help train these specific components. Elderly people or people with brain damage could benefit from the effects of gaming on their cognitive abilities and on thinking tasks (such as divergent and convergent thinking). Furthermore we could use these techniques to learn children from a young age to think differently, instead of following the exact pattern the education system has laid out. Learning children to think differently can lead to problem solvers and other innovations we can now only dream off, or even worse: did not even think about.

The biggest limitation in both studies was our subject pool. The number for the first study was acceptable, although a larger pool probably would have given us more power. More subjects could mean we would find an effect, if there is any effect at all of course, instead of missing out. In our second study the subject pool was too limited, but that is one of the reasons the second study is used as an explorative pilot. If we found nothing at all it may not worth further research. But the results look promising to replicate with a larger sample, since we already found some interesting interactions. Furthermore, in the pilot study the videofiles and software did not always meet up to our expectations. Some files were corrupted and could not be used for the analysis. This makes a big difference, especially with so few participants to start with. This could be avoided with a larger sample or by using electrodes instead of webcams and software. Another more theoretical limitation of our study could be that we expected sport and dopamine to behave to same way as gaming and dopamine did on creativity. While both gaming and sport are linked to dopamine this does not necessarily mean they also react the same and give the same effects. We found that both variables did not behave the way that we expected, which may still suggest that they do behave alike. But this is something that should be researched further on different studies.

For further research, we suggest investigating this topic with a larger sample. With a larger sample the power of the study will go up and the chances of finding an effect (if it is there) will increase. Certainly for our pilot study, since we only explored our hypothesis with fourteen participants. But even in the observational study more participants would be welcome. This also makes sure the data are normally distributed and the effect of outliers will be taken away. For the pilot study a change in the measuring of the EBRs can be made as well. It was very practical to use webcams and eye blink detection software, but analyzing the data was a lot harder. There were a lot of corrupted files and the precision of the software is debateable as well. Using electrodes around the eyes, like Chermahini and Hommel (2010), may be less practical, but will also have less errors than the combination of webcams and software did. Furthermore, for further research a few changes can be made to the existing study. In this study we found no relationship between sports and convergent thinking, which led us to believe this may have had something to do with recreational or competitive exercising. In a follow-up study these two groups can be split up and compared with each other to investigate this theory. And as mentioned above, the relationship between sport, gaming and dopamine should be investigated. We expected dopamine to behave the same way on gaming and on sports, since both gaming and sports are linked to dopamine. This assumption should be further investigated to see if this is really the case.

In sum, we showed that there is indeed a relationship between creativity, gaming and sport. But this relationship has to be researched further, with a larger subject pool. The results of these studies look promising, but they lack the power to draw any conclusion. But if you want to improve your convergent thinking, it seems to be beneficial to play creativity rewarding games.

References

Almeida, L. S., Prieto, L. P., Ferrando, M., Oliveira, E., & Ferrándiz, C. (2008). Torrance Test of Creative Thinking: The question of its construct validity. *Thinking Skills and Creativity*, *3*(1), 53–58. http://doi.org/10.1016/j.tsc.2008.03.003

Alves, H., Voss, M. W., Boot, W. R., Deslandes, A., Cossich, V., Salles, J. I., & Kramer, A. F. (2013). Perceptual-cognitive expertise in elite volleyball players, *4*(March), 1–9. http://doi.org/10.3389/fpsyg.2013.00036

Bilker, W. B., Hansen, J. A., Brensinger, C. M., Richard, J., Gur, R. C. R. E., & Gur, R. C. R. E. (2012). Development of abbreviated nine-item forms of the Raven's standard progressive matrices test. *Assessment*, *19*(3), 354–69. http://doi.org/10.1177/1073191112446655

Boot, W. R., Blakely, D. P., & Simons, D. J. (2011). Do action video games improve perception and cognition? *Frontiers in Psychology*, *2*(SEP), 1–6. http://doi.org/10.3389/fpsyg.2011.00226

Chermahini, S. A., & Hommel, B. (2010). The (b)link between creativity and dopamine: Spontaneous eye blink rates predict and dissociate divergent and convergent thinking. *Cognition*, *115*(3), 458–465. http://doi.org/10.1016/j.cognition.2010.03.007

Chermahini, S. A., & Hommel, B. (2012). More creative through positive mood? Not everyone! *Frontiers in Human Neuroscience*, *6*(November), 319. http://doi.org/10.3389/fnhum.2012.00319

Colzato, L. S., Van Den Wildenberg, W. P. M., Van Wouwe, N. C., Pannebakker, M. M., & Hommel, B. (2009). Dopamine and inhibitory action control: Evidence from spontaneous eye blink rates. *Experimental Brain Research*, *196*(3), 467–474. http://doi.org/10.1007/s00221-009-1862-x

Colzato, L. S., van Leeuwen, P. J. A., van den Wildenberg, W. P. M., & Hommel, B. (2010). DOOM'd to switch: Superior cognitive fl exibility in players of first person shooter games. *Frontiers in Psychology*, *1*(APR), 1–5. http://doi.org/10.3389/fpsyg.2010.00008

Cropley, A. (2006). In Praise of Convergent Thinking. *Creativity Research Journal*, *18*(3), 391–404. http://doi.org/10.1207/s15326934crj1803

Gilhooly, K. J., Fioratou, E., Anthony, S. H., & Wynn, V. (2007). Divergent thinking: Strategies and executive involvement in generating novel uses for familiar objects. *British Journal of Psychology*, *98*(4), 611–625. http://doi.org/10.1348/096317907X173421

Gocłowska, M. A., Baas, M., Crisp, R. J., & Dreu, C. K. W. De. (2014). Whether Social

Schema Violations Help or Hurt Creativity Depends on Need for Structure. *Personality and Social Psychology Bulletin*, *40*(8), 959–971. http://doi.org/10.1177/0146167214533132

Guilford, J.P., Christensen, P.R., Merrifield, P.R., & Wilson, R.C. (1978). Alternate Uses: Manual of instructions and interpretations. Orange, CA: Sheridan Psychological Services.

Jackson, L. A., Witt, E. A., Games, A. I., Fitzgerald, H. E., Von Eye, A., & Zhao, Y. (2012). Information technology use and creativity: Findings from the children and technology project. *Computers in Human Behavior*, *28*(2), 370–376. http://doi.org/10.1016/j.chb.2011.10.006

Karson, C. N. (1983). Spontaneous eye-blink rates and dopaminergic systems. Brain, 106, 643–653

Koepp, M. J., Gunn, R. N., Lawrence, A. J., Cunningham, V. J., Dagher, a, Jones, T., … Grasby, P. M. (1998). Evidence for striatal dopamine release during a video game. *Nature*, *393*(6682), 266–8. http://doi.org/10.1038/30498

Lorenz, R. C., Gleich, T., Gallinat, J., Kühn, S., Boot, W. R., & State, F. (2015). Video game training and the reward system, *9*(February), 1–9. http://doi.org/10.3389/fnhum.2015.00040

Mayseless, N., Uzefovsky, F., Shalev, I., Ebstein, R. P., & Shamay-Tsoory, S. G. (2013). The association between creativity and 7R polymorphism in the dopamine receptor D4 gene (DRD4). *Frontiers in Human Neuroscience*, *7*(August), 502. http://doi.org/10.3389/fnhum.2013.00502

Mccrae, R. R. (1987). Creativity , Divergent Thinking , and Openness to Experience, *52*(6), 1258–1265.

Mednick, S. A., & Mednick, M. T. (1972). Remote Associates Test. *Journal of Education Measurement*, *9*(2), 161–162. Retrieved from http://www.jstor.org/stable/1433810

Meeusen, R., & De Meirleir, K. (1995). Exercise and Brain Neurotransmission. *Sports Medicine*. Brussel. http://doi.org/10.2165/00007256-199520030-00004

Oei, A. C., & Patterson, M. D. (2013). Enhancing Cognition with Video Games: A Multiple Game Training Study. *PLoS ONE*, *8*(3). http://doi.org/10.1371/journal.pone.0058546

Pain, M. (2005). Risk taking in sport. *Lancet*, *366*(December), 33–34. http://doi.org/10.1016/S0140-6736(05)67838-5

Shukla, D. (1985). Blink rate as clinical indicator. Neurology, 35, 286

Taylor, J. R., Elsworth, J. D., Lawrence, M. S., Sladek, J. R., Jr., Roth, R. H., & Redmond,

D. E. Jr., (1999). Spontaneous blink rates correlate with dopamine levels in the caudate nucleus of MPTP-treated monkeys. Experimental Neurology, 158, 214–220

Toril, P., Reales, J. M., & Ballesteros, S. (2014). Video game training enhances cognition of older adults: A meta-analytic study. *Psychology and Aging*, *29*(3), 706–716. http://doi.org/10.1037/a0037507

Voss, M. W., Kramer, A. F., Basak, Chandramallika, Prakash, R. S., & Roberts, B. (2009). Are Expert Athletes â€™ Expert â€™ in the Cognitive Laboratory ? A Meta- Analytic Review of Cognition and Sport Expertise. *Applied Cognitive Psychology*, (June 2017). http://doi.org/10.1002/acp

Wang, G. J., Volkow, N. D., Fowler, J. S., Franceschi, D., Logan, J., Pappas, N. R., … Netusil, N. (2000). PET studies of the effects of aerobic exercise on human striatal dopamine release. *Journal of Nuclear Medicine : Official Publication, Society of Nuclear Medicine*, *41*(8), 1352–1356. Retrieved from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=pubmed&cmd=Retrieve&dopt=AbstractPlus&list_uids=10945526

Yeh, C. S. H. (2015). Exploring the effects of videogame play on creativity performance and emotional responses. *Computers in Human Behavior*, *53*, 396–407. http://doi.org/10.1016/j.chb.2015.07.024