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Stand up if you mind!

How does body position affect creativity and problem solving?

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Preface

This thesis is written to improve sessions in the LEF future center of Rijkswaterstaat and to extent their knowledge about improving cognitive performance**.** Rijkswaterstaat (RWS) is the executive organization of the ministry of infrastructure and environment. RWS has the mission to provide a safe, livable and sustainable environment in The Netherlands. Due to this important task RWS faces a lot of challenges. To meet these challenges, innovation and creativity are needed. To stimulate innovative and creative processes of the employees of RWS the LEF Future Center (hereafter LEF) was founded. LEF has a 3000 m2 workspace at its disposal, which includes a big conservatory, a theater and different areas where the environment can be adjusted to facilitate the project group's goal. A facilitator, who designs the sessions, guides the project group through the process. The main goal of LEF is to let the employees leave the sessions with clear results that will improve their processes.

The fundament of the concept of LEF is "brain learning" which is supported by neuroscientific research from social and cognitive psychology. For example, studies have been carried out on the effect LEF images have on convergent individual, convergent social, divergent individual and divergent social thinking (Van der Leij, Scholte & Lamme, 2011). Studies have also been carried out on how light intensity affects creativity (Hubregtse, 2014). However, most of the studies in LEF focus on how external stimuli manipulate a cognitive process but not on how internal stimuli (the body itself) can manipulate a cognitive process. In this study it will be examined how the body itself and thereby its internal process will manipulate cognitive performance.

I want to thank my colleagues of the LEF future of giving me the possibility to do research, especially Ingrid Renirie and Robert Verheule. Thanks to my supervisor, Guido Band, for keeping me sharp during the writing process. I also want to thank Mickey Koster for being the second rater, Eva Leusink for keeping me sharp during the analysis, Ramona Mendis-Seneviratne for doing some editing, Tyron Offerman for helping me making new templates for the TMT and Luuk Visser for making the laptop stands. And last but not least my friends and family for their moral support.

Leiden, June 2015 Lindsey van der Lans

Abstract

In this thesis the effect of body position on creativity and problem solving is studied. Body position affects arousal and arousal affects cognitive flexibility, which is an important element of creativity and problem solving. In this study four different body positions have been studied: standing, supine, passive sitting and active sitting. In all four conditions people completed the Alternative Uses Test (AUT) and the Remote Association Test (RAT) as indices of divergent and convergent thinking, and the Trail Making Test (TMT) to index mental speed and cognitive flexibility. The results show that standing is beneficial for divergent thinking and having an active position is beneficial for cognitive flexibility. More research is necessary on how body position affects arousal and how active and passive body positions affect cognitive performance.

Keywords: Embodied cognition, affordances, cognitive flexibility, arousal, creativity, problem solving, body position

Introduction

People are always having their body; therefore it seems highly relevant to study how body position affects cognitive performance on creativity and problem solving. So far, not much research has been done on how body position can manipulate cognitive performance. However, some research shows that body position is a determinant in neuroimaging (Thibault, Lifshitz, Jones & Raz, 2014). This suggests that body position might affect cognitive performance. For example, Lipnicki and Byrne (2005) show results that a supine body position shows better results on insight problem solving compared to standing. They suggest that it is due to the level of arousal. Since we carry our body everywhere it seems highly relevant to study how body position affects cognitive performance on creativity and problem solving.

In this thesis the effect of body position on cognitive performance, creativity and problem solving will be studied. First the topics creativity and problem solving will be explained, and how cognitive performance can be enhanced by altering the environment. Second, information about how body position affects arousal and what the implications are of arousal on cognitive flexibility will be given.

Creativity, problem solving and the environment

Creativity is the process of relating different cues in a novel way (Heilman, Nadeau & Beversdorf, 2003). It is the generation of ideas, insights, or problem solutions that are both novel and potentially useful to improve one's effective functioning (Baas, De Dreu & Nijstad, 2008). Kirton (2003) even states that creativity is a subset of problem solving. Moreover, creativity belongs to the same cognitive function as problem solving. Guilford (1967) divided creativity into two main components: divergent thinking and convergent thinking. Many studies are using this distinction to study creativity, which is shown in the meta-analysis of Baas, De Dreu and Nijstad (2008).

Divergent thinking is the ability to produce as many ideas as possible, from the given cues (Guilford, 1967). The performance on divergent thinking is measured along four different components: fluency, flexibility, originality and elaboration. Fluency is the total number of ideas generated. Flexibility is someone's ability to switch between different categories. Originality is measured by the performance of how uncommon one's ideas are compared to others. Elaboration is the amount of detail given (Baas, De Dreu & Nijstad, 2008). This can be measured by the alternative uses test (AUT), which will be discussed later. Convergent thinking is the ability to solve problems with a fixed solution; the unique answer is determined by the given cues (Guilford, 1967). This can be measured by the remote associates test (RAT), which will be elaborated later as well (Baas, De Dreu & Nijstad, 2008).

Cognitive flexibility is the underlying mechanism of creativity. Cognitive flexibility is the ability to overcome fixedness and to breakthrough old patterns by assessing alternative networks (Guilford, 1967; Ritter et al., 2012). The environment can manipulate cognitive flexibility to enhance creativity. Ritter et al. (2012) studied how diversifying experiences can enhance creativity by letting participants experience unusual events in virtual reality. Moreover, Rietveld et al. (2014) state that different environments can promote creativity. Working in a different practice can change the way a person perceives a given cue. More specific, when working in a different environment with the same objects can reveal different affordances, therefore it can lead to different insight of how to use the objects.

Research has been done as to what kind of images can manipulate creativity. These images can enhance individual divergent/convergent thinking and social divergent/convergent thinking. Pictures with animals and other people enhance social thinking, while individual thinking is enhanced by serene images activating internal processes. Convergent thinking is enhanced by images with a clear focus and divergent thinking is enhanced by pictures that suggest some action (Van der Leij, Scholte & Lamme, 2011).

Moultrie et al. (2007) underpinned the importance of spaces to enhance creativity and innovation. They gave the environment an important role in a framework to accomplish the strategic goals of an organization. Moreover, Dul and Ceylan (2010) did a meta-analysis on how the physical environment can improve employee creativity. The study showed that furniture, plants, colors, daylight and many more elements do enhance employee creativity. For the purpose of this thesis the focus will be on furniture, to be more specific, the body position that is evoked by furniture.

Embodied cognition

How body position is evoked by furniture can be described by the theory of affordances. Gibson (1979) was an ecological psychologist who posited the theory of affordances. *The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill* (p.127). This means that the environment in itself shows how to be used. For example, a chair has the affordance of sitting, so people go sit on it, but it also has a flat surface, so you can also stand on it. The affordance of an object is always present, independent of what people need or what their intentions are.

Barsalou (2008) states that cognition is grounded in different aspects such as in the environment (affordances) but also in bodily experiences. Which is called embodied cognition and is well explained in the following citation:

> *"The mind is no longer conceived of as a set of logical/abstract functions, but as a biological system rooted in bodily experience and interconnected with bodily action and interaction with other individuals."* (Garbarini & Aldenzato, 2004, p. 105)

Since people are guided by the environment, they do automatically adjust to different body positions. Most of the time one is not conscious of their body position or limbs; however research shows that it affects cognitive performance.

Friedman and Forster (2002) showed that arm flexion and arm extension have an effect on creativity, where arm flexion enhanced creativity. Arm flexion is associated with approach, when a person flexes his arm it is to bring something you want closer. In contrast, arm extension goes away from the person and is therefore associated with avoidance (Friedman & Forster). It is shown that arm flexion promoted insight thinking, whereas arm tension promoted analytical reasoning. Moreover, Hao, Yuan, Hu and Grabner (2014) found that when people flex their arms (approach) people become more creative compared to extension (avoidance) of the arm. They tested this approach and avoidance when people were seated and supine.

Lipnicki and Byrne (2005) studied whether people could solve anagrams in higher speed when supine compared to standing. The result of this study is that when people are supine, anagrams are solved faster. Knight and Baer (2014) studied the effect of a non-sedentary group performance. Their findings are that the performance on knowledge work increased. A non-sedentary workplace enhances information elaboration between employees, in contrast to a sedentary workplace. Moreover, Thibault et al. (2014) studied if body position (standing, sitting, supine and inclined 45°) alters the human resting-state. The result was that frontal and occipital brain activity increased when standing.

The embodied aspect of these studies seems to be arousal. Lipnicki and Byrne (2005) associate their results with the increased level of arousal when standing compared to lying. Knight and Baer (2014) also showed that the level of arousal increased in the non-sedentary workplace. Thibault and colleagues (2014) also endorse that arousal decreases when supine, due to the decline of Noradrenaline by the Locus Coeruleus. The next section will elaborate on how arousal affects cognitive performance.

In sum, the environment contains different affordances; these affordances evoke a certain use of the object. So furniture, suggests certain body positions and body position can be passive (avoidant) or active (approaching), and body position affects arousal. Which in turn affect creativity and problem solving.

Arousal

Arousal is a behavioral state and is mediated in the body by responses of the peripheral nervous system to environmental challenges. Psychological factors and physical factors correlate with brain activity; therefore brain activity is playing a mediating role in behavioral state (arousal) in the central nervous system. Accordingly, behavioral state and neuromodulatory systems influence cognition (Sara & Bouret, 2012).

The underlying neuromodulatory system that mediates arousal is the release of noradrenaline by the Locus Coeruleus (LC-NE). People perform their best if arousal is at an intermediate level. This is called the inverted U-theory and is described by the Yerkes-Dodson curve. Aston-Jones and Cohen (2005) posit the adaptive gain theory which is based on the inverted u-theory. This theory proposes that the LC-NE system is responding to the environment and it has two different modes; the tonic mode and the phasic mode. The phasic mode is active when people are engaged in a certain task and promotes accuracy and focus. In behavioral terms; it encourages exploitation. The tonic mode becomes active when people are distracted from the current task. In behavioral terms it means that people start to explore. This LC-NE system makes exploration and exploitation possible which is important for creativity on the aspects of convergent and divergent thinking. The LC-NE system facilitates that when people are exploiting and need more information they will shift to exploration, and the other way around. According to Aston-Jones and Cohen (2005) low (non-alert) or high (distractible) tonic activity decreases performance. Performance is best when there is a moderate activity of the tonic mode.

Arousal affects cognitive performance such as attention and decision-making (Aston-Jones & Cohen, 2005) and cognitive flexibility (Beversdorf, Hughes, Steinberg, Lewis & Heilman, 1999; Campbell, Tivarus, Hillier & Beversdorf, 2008). Cognitive flexibility is the ability to solve different tasks by accessing different networks. For example, the RAT challenges people to find the right association for three different words. To solve such insight problems people have to access their semantic and associative networks (Bowden & Jung-Beeman, 2003). However, it is shown that a higher level of arousal is not beneficial for solving insight problems (Beversdorf et al., 1999; Lipnicki & Byrne, 2005).

Moreover, arousal plays an important role in exploitation versus exploration behavior (Aston-Jones & Cohen, 2005) and these processes are important for creativity (Seo, Chae & Lee, 2015). Exploitation is to pursue a known source and is the process of selection, refinement, decision-making and implementation; it seems to be the behavioral state of convergent thinking. Exploration is searching for new ideas; it is the process of risk taking, flexibility, discovery and innovation (Seo, Chae, & Lee, 2015). Exploration seems to be the behavioral state of divergent thinking. Exploitation can be

seen as more deliberate behavior compared to exploration, since people have to think carefully about the given cues.

In sum, the environment has an influence on how people behave and to which body position they adjust. Different body positions evoke different levels of arousal and this affects cognitive flexibility. Cognitive flexibility is important for creativity and problem solving. The central question of this thesis is: Does body position affect creativity and problem solving?

Participants in the current study will be tested in four different body positions: supine, passive sitting, standing and active sitting. There are two underlying mechanisms why these body positions are chosen. Arousal slightly increases when people are standing and decreases when supine. An approach body position facilitates creativity, therefore active sitting is chosen. An avoidance body position decreases creativity, therefore passive sitting is chosen.

The first hypothesis is: Standing and active sitting will improve divergent thinking (exploration), compared to the other body positions. This will be tested with the AUT. This test measures fluency, flexibility, originality and elaboration. These aspects are indicators of divergent thinking (Chermahini, Hickendorff & Hommel, 2012).

The second hypothesis is: Supine and passive sitting will improve convergent thinking (exploitation), compared to the other body positions. This will be tested with the RAT. People have to find a fourth word that associates with three given words. There is a fixed solution and therefore the RAT is an indicator of measuring insight problems (Chermahini, Hickendorff & Hommel, 2012). The TMT measures the reaction time on completing the trail. This test is an indicator of mental speed and cognitive flexibility (Strauss, Sherman & Spreen, 2006). The research design is a repeated measures design.

Materials and Methods

Participants

A recruiting agency was asked to recruit seventy participants. Sixty-eight participants were recruited in the end. All the 68 participants finished the complete test, however if someone did not understand the task they were excluded from the data. There were 37 female participants and 31 male participants. Age was *M* = 31.6 years, *SD* = 4.3, minimum age was 25 and maximum age was 40. Sixty-seven participants did not report any disabilities in one of the body positions. The recruitment agency had the task to recruit higher educated people. Thirty people were HBO-educated (university of applied sciences), 36 university-educated and two MBO-educated (vocational education). Another question asked was how energized they felt at the moment on a 7 point Likert Scale (1 = not having energy at all; 7 = very energetic), *M* = 4.57, *SD* = 1.23.

Material

All the tests were done on Fujitsu laptops, which belong to the LEF future center. The participants were not allowed to use the touchpad of the laptop, but they had to use the wired optic mouse. The output of the AUT and RAT for this paper was collected using Qualtrics software (Version 4-2015; Provo, UT, 2015). Inquisit (Version 4; Seattle, WA, 2015) was running the TMT and also collected the data. Both software programs were online programs and Internet Explorer was the best compatible browser. Different furniture was used to support the different body postures. The furniture was placed in ten rows, in these rows the following furniture were aligned: an aluminum stool, an in height-adjustable table, a chair, a sports mat with a small and big pillow and a laptop table (figure 1).

Figure 1 Picture of research area during pilot study

Cognitive Tasks

The RAT is used to measure convergent thinking and is also associated with the ability to solve insight problems. In this test, three words were given and the participant has to think of a fourth word that is associated with all the three words. For example, if the words dream, break, light are given the associated word is day. This test is originally in English but Chermahini, Hickendorff and Hommel (2012) created a validated Dutch version of the RAT. This Dutch version has 30 well-validated items. The time participants had to complete the original test in 10 minutes. However, this design has four conditions, so four batches of seven word combinations were given. The participants have 2.5 minutes to answer the seven given items.

The AUT measures divergent thinking on: fluency (total of all responses); flexibility (number of different categories), originality (unusual 5% or unique 1% ideas compared to the group) and elaboration (the amount of detail) (Chermahini, Hickendorf & Hommel, 2012). The items that will be given in Dutch are: brick, shoe, paperclip and pen. The AUT is considered as a valid measurement for divergent thinking and to keep in line with earlier research the participants have 2 minutes to come up with as many applications for the objects as possible (Chermahini, Hickendorf & Hommel, 2012).

The TMT is a test to measure mental speed and cognitive flexibility. The TMT consists of part A and part B. Part A has 25 encircled numbers which the participant has to connect to one another in the right order. Part B has in total 13 encircled numbers and 12 encircled letters, which have to be connected to one another in the right order (1-a-2-b-3-c-..etc.)(Strauss, Sherman & Spreen, 2006). The purpose of this task is to connect the numbers and letters as fast as possible in the right order. This will be measured in reaction time by Inquisit (Version 4; Seattle, WA, 2015). Moreover, the ratio and difference scores are indicators for cognitive flexibility. Inquisit (Version 4; Seattle, WA, 2015) already had one version, although four were needed so three others are developed. The test has been adjusted in Inquisit Lab (Version 4; Seattle, WA, 2015) by replacing the circles by retrieving new coordinates by a randomizer.

Design

This study is 1x3 repeated measures design. The independent variable is body posture and has four conditions: supine, standing, active sitting and passive sitting. The participants will complete in every body position the following tests: AUT, RAT and TMT. The tests are given in different orders. Moreover, the body postures are counterbalanced on the tests. Table 1 shows how the conditions were counterbalanced.

Table 1 Counterbalancend body positions between groups.

Test	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
AUT	Supine	Passive	Active	Stand	Supine	Stand	Passive
RAT	Supine	Passive	Active	Stand	Supine	Stand	Passive
TMT	Supine	Passive	Active	Stand	Supine	Stand	Passive
RAT	Passive	Active	Stand	Supine	Active	Passive	Supine
TMT	Passive	Active	Stand	Supine	Active	Passive	Supine
AUT	Passive	Active	Stand	Supine	Active	Passive	Supine
TMT	Active	Stand	Supine	Passive	Stand	Supine	Active
AUT	Active	Stand	Supine	Passive	Stand	Supine	Active
RAT	Active	Stand	Supine	Passive	Stand	Supine	Active
AUT	Stand	Supine	Passive	Active	Passive	Active	Stand
RAT	Stand	Supine	Passive	Active	Passive	Active	Stand
TMT	Stand	Supine	Passive	Active	Passive	Active	Stand

Procedure

The participants were recruited by a recruitment agency, CG selections. The participants received 35 euro for 1.5 hours of participation. At the entrance the researcher welcomed the participant and handed over the informed consent form which every participant signed.

First it was explained to the group what would happen in the coming hours. They were told to only use the wired optic mouse to navigate and not the touchpad on the laptop. Moreover, the changing of the body position needed to happen simultaneously, which is why the participants had to wait for a sign of the researcher. First, they all had to wait 5 minutes, in every condition, so that the body could adjust to the new posture (Lipnicki & Byrne, 2005). Second, they completed the AUT, RAT and TMT in different orders (table 1). The respondent numbers were written on the badge they were carrying so it did not cost any cognitive effort to remember this. The participants were helped

by the researcher when changing body position. Afterwards they could go to the waiting area and the participants could ask questions and received a debriefing letter.

The body positions were as shown in the figures 2-5. A remark for the supine condition is that only their head should be on the pillows (figure 2). A laptop stand was developed so that they could work supine. The laptop stand was placed over the participant at the level of their waist. For the passive condition it was important that they felt the support in their back.

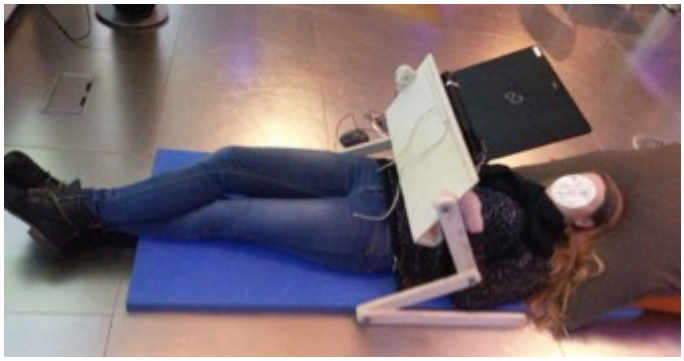

Figure 2 Supine Condition (instead of two thick pillows, we used a thin and thick pillow)

Figure 3 Active sitting

Figure 4 Passive sitting

Figure 5 Standing

Data analysis

The TMT yields reaction times for part A and part B. Difference score (B-A) and the ratio score (B/A) were calculated as indicators for cognitive flexibility (Strauss, Sherman & Spreen, 2006). Both the RAT and the AUT were scored as suggested by Chermahini et al. (2012). The score on the RAT consisted of the number of correct answers given by the participant.

The AUT was scored on four different aspects; flexibility, elaboration, originality and fluency. The fluency is the total number of ideas generated by the participant. Flexibility is the total number of categories the participant was thinking in. The response categories were defined as follows for the four AUT assignments. Paperclip: to insert in something, to connect something, to clean or fix something, to deform it, metal, using the sharpness, the paperclip itself does nothing. Shoes: wearing them, to move them, to clean/fix/adjust them, something with the laces, to put something in it, to look at it, to use it in a completely alternative way. Pen: write on paper, to insert it in something, use it in a violent way, use it on your body, to indicate something, to move it, the pen itself does nothing. Brick: to build something, use it in a violent way, to move it, changing the substance, use the weight, use it for a game, remaining applications. Originality was scored on the basis of how many participants gave the same answer. If three people or less (5%) gave the same answer, the score was 1 point (unusual). If only one person (1%) gave the answer, the score was 2 points (unique). Elaboration scores indicated the extent to which the participant gave an explanation of the application they were giving. For example, to mention paint as an alternative use for a pen yielded zero points, to remove ink and paint scored one point and to remove ink and paint with it to create a decorated wall scored two points.

Subjective AUT measures (flexibility and elaboration) were scored by two independent raters who were blind to the posture conditions after the response categories were determined. Therefore, interrater reliability is used to assess the degree to which both raters made consistent observations of the yield (Multon, 2010).

To analyze the data, repeated measures ANOVAs were used to analyze the effect of body position on the RAT, AUT and TMT. Afterwards, the Bonferroni post hoc test will be done, to investigate the differences between the body positions. Moreover, extreme outliers passing the third inter quartile range are excluded from the data.

Results

Creativity

Creativity has been measured by the AUT, which has four different components. All these components are analyzed by a repeated measures ANOVA. Moreover, the interrater reliability is tested for flexibility and elaboration, since these are the most subjective parts of the AUT. Spearman's correlation is used since the normal distribution is violated (Multon, 2010).The correlation is calculated between the means of the participants on flexibility (R_S =.858, p < 0.01) and elaboration (R_S =.75, p. < 0.01. According to Field (2014), it is no issue for running the repeated measures ANOVA, since the sample size is big enough and the extreme outliers are excluded.

Fluency

First of all the results of fluency, in total 68 participants were participating in the study. However, one participant did not understand the assignment and after removing outliers 63 participants remained. Mauchly's test indicated that the assumption of sphericity has been met, χ^2 (5) = 9.39, *p* = .095. The results show that body posture significantly affected the fluency, F (3, 186) = 4.37, *p* = .005, partial η^2 =0 .066. Supine, *M* = 7.86, *SD* = 3.05; Passive, *M* =8.46, *SD* = 3.09; Active, *M* = 8.73, *SD* = 3.56; Standing, *M* = 9.38, *SD* = 3.32. For the post hoc test the Bonferroni method is used. This shows that there is a difference between the supine and standing condition, *p* = .004. Moreover, the difference between passive sitting and standing is almost significant *p* = .069. In sum, when supine, people generate fewer ideas compared to standing. However, some participants told afterwards that it was not easy to type in the supine position. This might clarify, why the score on fluency is significantly lower in the supine condition. If the sample size would be bigger, the same result might have been found between passive sitting and standing.

- People are generating more ideas when standing.

Flexibility

The data of flexibility did not show any outliers, *N* = 67. Mauchly's test for sphericity is assumed, χ^2 (5) = 5.79, *p* = .328. However no significant effect has been found on the effect of body posture on flexibility, F (3, 198) = 2.25, *p* = .084, partial η^2 =0 .033. Supine, *M* = 3.91, *SD* = 1.29; Passive, *M* = 4.21, SD = 1.27; Active, *M* = 3.91, *SD* = 1.43; Standing, *M* = 4.27, *SD* = 1.24. This means that there is no difference between the body positions and the ability to switch between categories.

- Body position has no effect on flexibility.

Originality

The sample in the category of originality is corrected for outliers, N = 62. The assumption for the Mauchly's test for sphericity is met, χ^2 (5) = 5.24, *p* = .387. However, no effects have been found, F (3, 183) = .403, *p* = .751, partial η^2 =0 .007. Supine, *M* = 3.81, *SD* = 3.238; Passive, *M* = 4.15, *SD* = 3.19; Active, *M* = 3.73, *SD* = 3.03; Standing, *M* = 4.08, *SD* = 2.82. This means that there is no difference between the body positions and creating original ideas.

- Body position has no effect on creating original ideas.

Elaboration

The last part of measuring creativity is elaboration. After correcting for outliers, *N* = 56 the assumption of Mauchly's test for sphericity is not met anymore. Therefore, to analyse the data the Huynh-Feldt correction will be used, ε = .902. The results are F (2.71, 148.84) = 7.051, *p* < .01, partial η^2 =0 .114. Supine, *M* = .07, *SD* = .26; Passive, *M* = .55, *SD* = .872; Active, *M* = .36, *SD* = .62; Standing, *M* = .41, *SD* = .80. This shows that body position has an effect on elaboration. After the Bonferroni post hoc test it is shown that there is a significant difference between supine and all of the other body positions, p ≤ .01. However, some participants told afterwards that it was not easy to type in the supine position. This might clarify, why the score on elaboration is significantly lower in the supine condition.

- When supine people are less elaborating on their ideas.

Conclusion

The main conclusion that can be drawn about creativity is that people generate more ideas while standing compared to lying. Also a moderate difference is shown between passive sitting and standing. This is in line with the hypothesis: people do think more divergent when they are standing compared to other body positions such as supine and passive sitting.

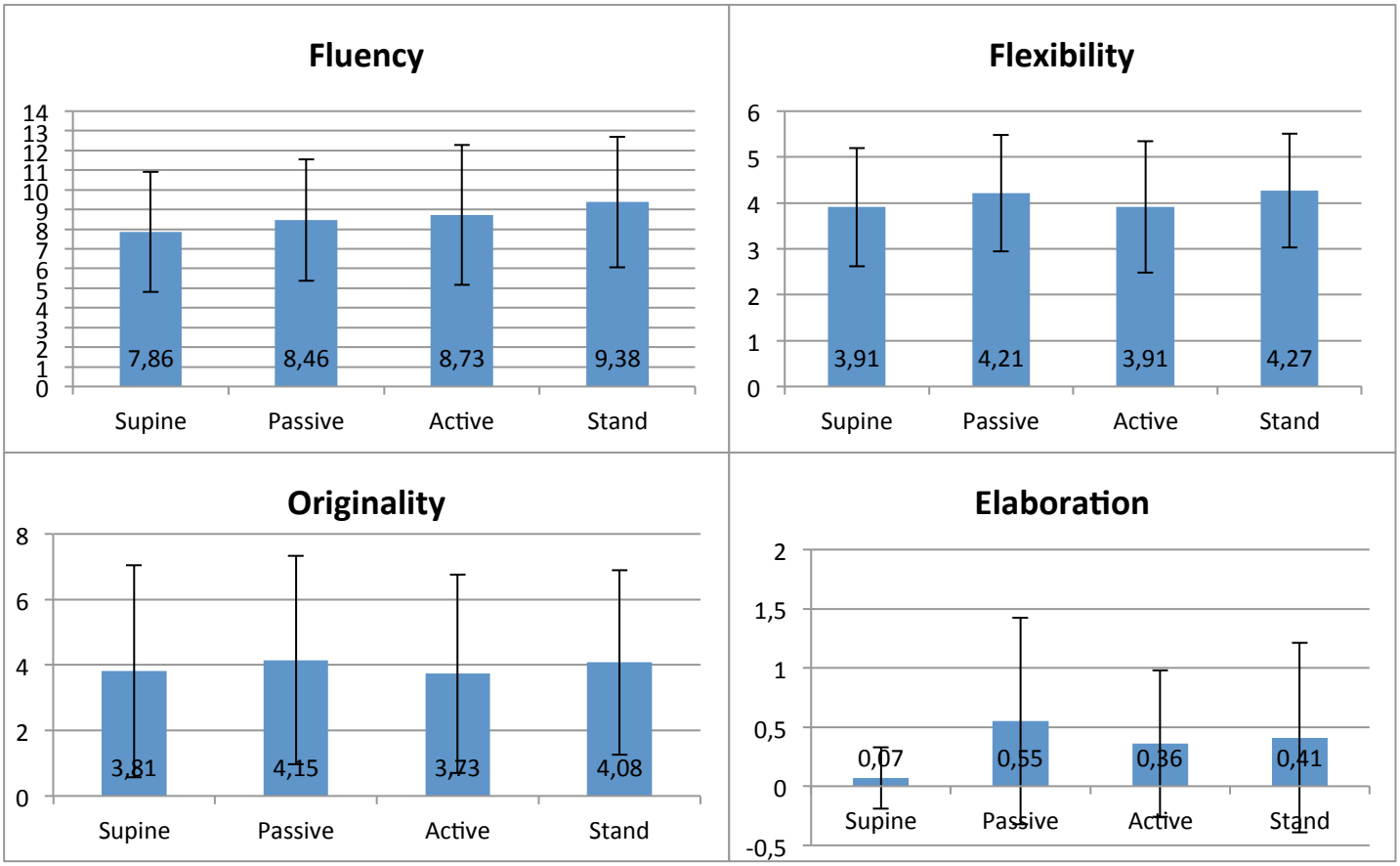

Figure 6 AUT components, mean and standard deviation

Insight problem solving

This has been measured with the RAT. Only one participant did not understand the test, 67 participants remained. Mauchly's test of sphericity is assumed. χ^2 (5) = 9.19, p = .102. However, no effect of body position on the RAT has been found, F (3, 198) = .886, p = .460, partial η^2 =0 .013. Supine, M = 2.94, SD = 1.74; Passive, M = 3.07, SD = 1.74; Active, M = 3.39, SD = 1.64; Standing, M = 3.09, SD = 1.69. This means that there is no difference between the body postures and the ability to solve insight problems. This is in contrast with the hypothesis. The literature shows that people are able to solve more insight problems when they are supine.

- Body position has no effect on insight problem solving.

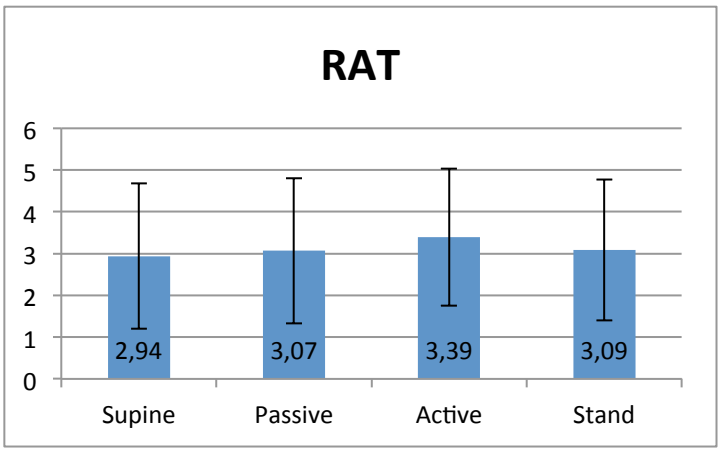

Figure 7 RAT mean and standard deviation

Mental speed and cognitive flexibility

Mental speed

For TMT part A 61 participants remained after removing scores > 180 seconds and removing outliers passing the third inter quartile range are removed. Mauchly's test of sphericity is assumed, χ^2 (5) = 5.92, p = .314. However, no effect have been found of body position on mental speed, F (3, 180) = 1.07, p = .36, partial η^2 =0 .02. Supine, M = 55.61, SD = 14.63; Passive, M = 53.41, SD = 15.32; Active, M = 51.76, SD = 12.68; Standing, M = 54.71, SD = 16.90. This means that body position has no effect on mental speed.

- Body position has no effect on mental speed.

Mental speed and cognitive flexibility

For TMT part B 61 participants remained after removing scores > 300 seconds and removing outliers passing the third inter quartile range are removed. Mauchly's test of sphericity is violated. χ^2 (5) = 17.88, $p < .01$. Therefore, the Huynh-Feldt correction is used, $\varepsilon = .884$. However, no effect has been found of body position on cognitive flexibility, F (2.65, 159.10) = .42, $p = .72$, partial η^2 =0 .01. Supine, $M = 71.82$, $SD = 24.87$; Passive, $M = 75.99$, $SD = 29.70$; Active, $M = 73.88$, $SD = 24.18$; Standing, $M = 76.64$, $SD = 35.11$. These results show that there is no difference between body position and mental speed on part B.

- Body position has no effect on mental speed challenging cognitive flexibility.

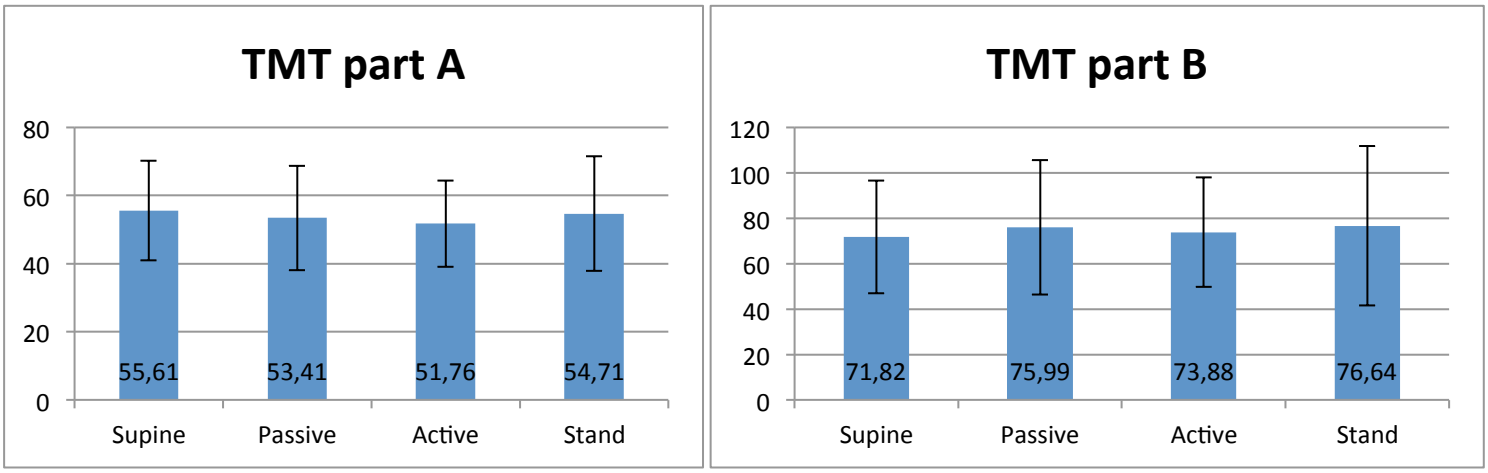

Figure 8 Mental speed, mean and standard devation

Cognitive flexibility

The ratio score between Part A and Part B has been calculated. The ratio score has to be > 0, this implies that for B/A, the participant should have a slower reaction time on part B compared to part A. After excluding data for this assumption and excluding one outlier, $N = 32$. The assumption for sphericity is not met χ^2 (5) = 11.96, $p = .04$. So the Huynh-Feld correction is used for the F-scores, $\varepsilon = .877$. A difference is shown between the body positions, F (2.63, 81.61) = 3.51, $p = .024$, partial η^2 = 0 .10. Supine, $M = 1.44$, $SD = .28$; Passive, $M = 1.66$, $SD = .52$; Active, $M = 1.38$, $SD = .29$; Standing, $M = 1.43$, $SD = .39$. After executing the Bonferroni post hoc test, it shows an effect between the active sitting and passive sitting condition $p < .05$. This means that active sitting and passive sitting have a different effect on cognitive flexibility. According to the means cognitive flexibility increases in the active condition.

- Active sitting increases cognitive flexibility

Since not much data is left when excluding scores < 0, a second analysis has been done. In this analysis only excluded the extreme outliers, passing the third inter quartile range, are removed

and 58 participants remained. The assumption for Mauchly's test of sphericity is met χ^2 (5) = 3.14, *p* = .68. However, no effect of body position on cognitive flexibility has been found, F (3, 171) = 1.93, *p* = .899, partial η^2 =0 .03. Supine, *M* = 1.26, *SD* = .36; Passive, *M* = 1.41, *SD* = .58; Active, *M* = 1.42, *SD* = .34; Standing, *M* = 1.37, *SD* = .42.

- Body position has no effect on cognitive flexibility.

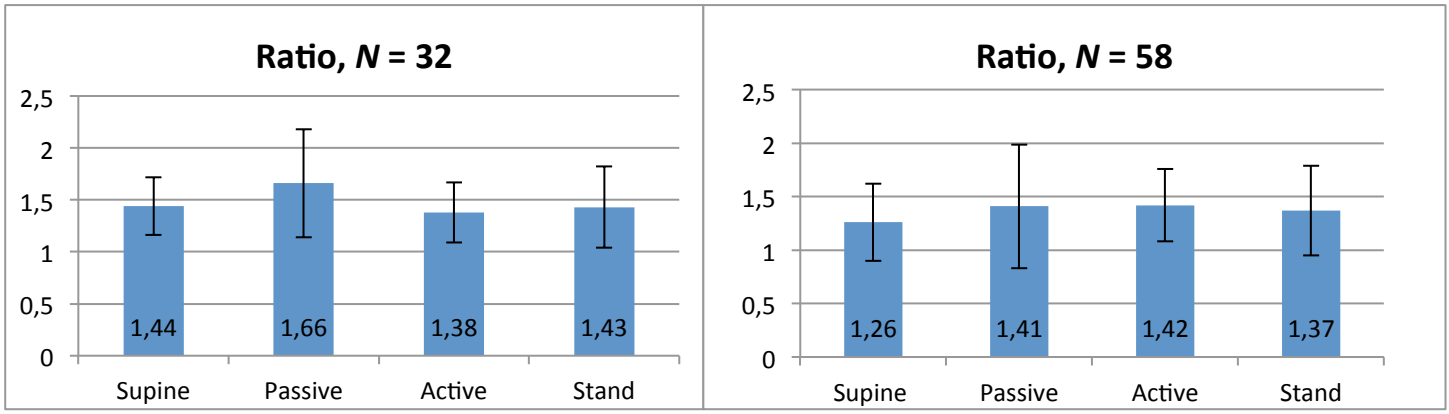

Figure 9 TMT ratio, mean and standard deviation

The last indication for cognitive flexibility is the difference score. After excluding part B < part A and the extreme outliers, passing the third inter quartile range, 32 participants remained. The assumption for sphericity is not met χ^2 (5) = 11.49, *p* = .04. So the Huynh-Feld correction is used for the F-scores, ε = .881. An effect has been found between the different body positions, F (2.64, 81.90) = 3.99, *p* = .014, partial η^2 = 0 .11. Supine, *M* = 21.71, *SD* = 12.19; Sit, *M* = 33.08, *SD* = 26.42; Active, *M* = 17.81, *SD* = 14.03; Standing, *M* = 21.38, *SD* = 19.61. The scores show significant effects, after executing the Bonferroni Post Hoc test it shows a difference between active sitting and passive sitting, *p* < .05. This indicates that cognitive flexibility increases in the active condition.

- Active sitting increases cognitive flexibility.

Since not much data is left when excluding part B < part A, a second analysis has been done. In this analysis only the extreme outliers, passing the third inter quartile range, are excluded and 54 participants remained. The assumption for sphericity is met χ^2 (5) = 9.51, *p* = .09. However, no effect of body position on cognitive flexibility has been found, F (3, 159) = 1.24, *p* = .30, partial η^2 =0 .02. Supine, *M* = 15.24, *SD* = 17.35; Sit, *M* =22.62, *SD* = 27.83; Active, *M* = 19.79, *SD* = 16.81; Standing, *M* = 17.76, *SD* = 20.50.

- Body position has no effect on cognitive flexibility

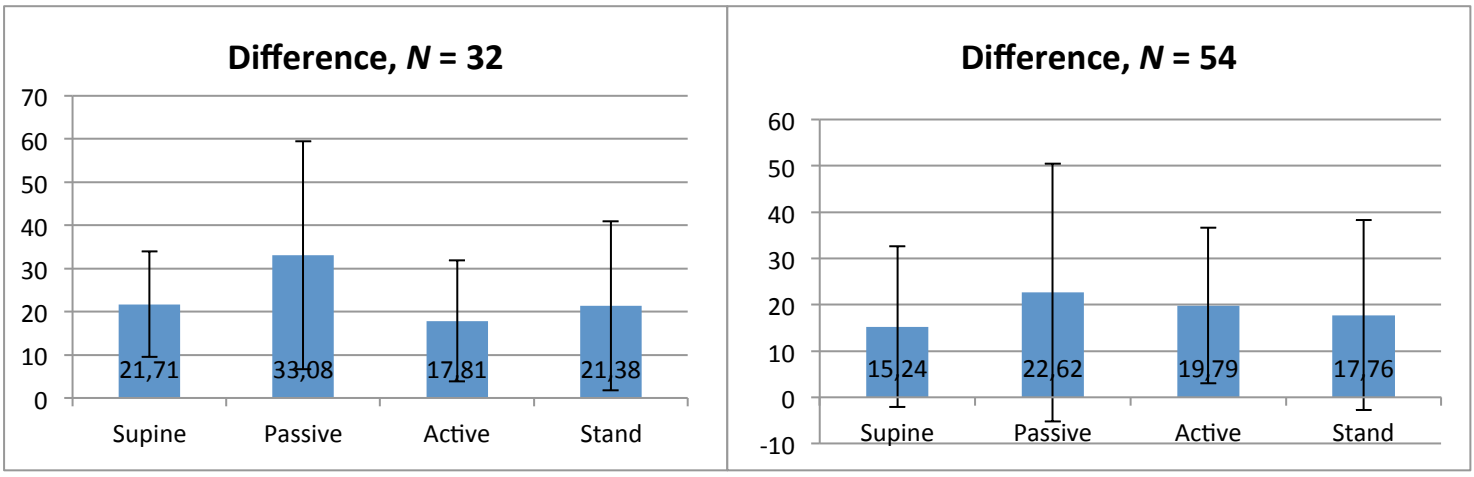

Figure 10 TMT difference score, mean and standard deviation

Conclusion

In sum, part A and part B do not show independent results. However, when looking at the ratio and difference score body position does show an effect on cognitive flexibility. Active sitting increases cognitive flexibility, however this is only shown in the smaller sample.

Discussion

Creativity

Creativity seems to be affected by body position. The results show that people are generating more ideas when standing and that people are the least elaborative when supine. This is in accordance to the hypothesis. However, the effect sizes are very small; this indicates that there have been other factors contributing to these results. One of the factors can be that the supine condition was not optimal compared to the other conditions. Some people were commenting afterwards that they liked the supine condition, especially the laptop stand, but they did not find it easy to type during the tests. A second factor might be tiredness. All the tests were done in the late afternoon and people might have come from work. Research shows that when people are tired and lying down, the body positions will negatively affect the cognitive performance compared to sitting (Muehlhan, Marxen, Landsiedel, Malberg & Zaunseder, 2014).

Another critical remark on elaboration is that the participants in general did not elaborate a lot. A consequence of this is that the scores on elaboration are very low. According to the study of Knight and Baer (2014) the highest score was expected in the standing condition on elaboration. Nonetheless, the results show the highest mean on elaboration in the passive sitting condition. This is in firm contrast to the study of Knight and Baer (2014). A factor that might have contributed to the results of Knight and Baer is that people were together in a group and were talking to each other

instead of writing everything down. The interaction between people and speaking out loud might contribute to elaboration.

Since standing enhances divergent thinking it can be suggested that people should be aware of the environment. As explained by the theory of affordances by Gibson (1979), an object affords to a person what can be done with it. For example, when having a brainstorm session, which implies divergent thinking, the furniture where people can sit on should be removed or reduced. However, research shows that it is best to stand for a limited period of time or alternate with sitting; otherwise people get tired and work performance will decrease (Hasegawa, Inoue, Tsutsue & Kumashiro, 2000).

Body position has no effect on flexibility and originality. Flexibility shows the amount of ideas generated between different categories. These categories are a subjective score, therefore interrater reliability has been calculated. Although there was a high correlation between the scores, it is still possible that two other raters will find other categories (Multon, 2010). This suggests that more or less categories can be deduced from the data, compared to this study. The inference that can be given for originality is that it does not make a difference in what kind of body position a person is.

In sum it can be said that supine seems not to be the optimal body position for divergent thinking. The optimal position for generating ideas is standing. This implies that, for example, during a brainstorm people should stand up. Another implication is standing during meetings. Research shows that standing meetings are more time efficient than sedentary meetings (Bluedorn, Turban & Love, 1999). Also, Knight and Baer (2014) showed positive results on standing meetings in the context of information sharing.

Insight problem solving

Insight problem solving is in this study not affected by body position. This is in contrast with the studied literature and the hypothesis. An explanation for this result is the limited items given per batch in the RAT. In the literature this is called a ceiling effect (Taylor, 2010), which can be prevented by expanding the number of given items. Another possibility is using different insight problem tests, such as anagrams or analogies (Baas, De Dreu & Nijstad, 2008). Lipnicki and Byrne (2005) used anagrams instead of the RAT when finding the result of being better in solving insight problems when supine. A possibility is that the participants were to highly aroused during the supine condition, because of the excitement of lying under a laptop. Accordingly, research showed that lower levels of arousal increases performance on the RAT (Beversdorf, et al., 1999). Higher levels of arousal can decrease performance, as proposed by the Yerkes-Dodson relationship (Aston-Jones & Cohen, 2005). On the other hand people had five minutes to adjust and accommodate to the new body position, and become quiet. In contrast, which is also offered by the inverted-U theory is that when people are

too relaxed (low arousal) this also decreases performance. As said in the former section this might have to do with reinforced tiredness by being supine (Muelhan et al., 2014).

In sum, the items per batch in the RAT should be expanded or other insight tests can be used. Moreover, the time to adjust to a new position should be extended.

Mental speed and cognitive flexibility

Mental speed is not affected by the different body positions. This is in contrast with the literature about approach and avoidance and about arousal. An underlying cause might be the new developed templates for the TMT, which will be explained later in this section.

Cognitive flexibility is affected by body position and shows a difference between the active and passive sitting conditions. According to the hypothesis active sitting promotes cognitive flexibility. This is in accordance with the research of Friedman and Foster (2002), where an approach body position increases performance. However, a critical remark is that this result is only shown for less than half of the sample. When using the bigger sample size, excluding the B >A criteria, the effect of body position on cognitive flexibility disappears.

When people took longer on the TMT than the given indication, for part A < 180 seconds and part B < 300 seconds, this had to do with technical (Wi-Fi) and software problems. Moreover, the means on part A in this test are higher compared to another study, where the mean was 37.9 seconds (Sanchez-Cubillo, et al., 2009). In contrast, the mean on part B in this study was slightly lower compared to the other study, which was 77.6 seconds. An explanation for these varying results might be due to the development of our own templates. This was necessary to reduce the contribution of a practice effect (Strauss, Sherman & Spreen, 2006). For creating the extra trials the only assumption was to randomly assign circles on a template, which was calculated by a randomizer. Compared to the original one, the difference for the new ones is that people had to go through their own drawn trails. Another explanation for the diversifying means is that one of the participants in the sixth group commented on the sensitive tuning of the mouse. It was said that it would have been easier to make the trail if the mouse was tuned less sensitive.

It can be recommended to sit in an active body position to increase cognitive flexibility. It appears that it does not make a difference in what body position a person is for mental speed. This implies that people can think equally as fast in any body position.

Integrative discussion

In this study it is examined if body position affects creativity and problem solving. The first hypothesis was: standing and active sitting will improve divergent thinking. The results confirm this hypothesis. Therefore, it might be the case that an approach posture affects exploration, as stated in the introduction. It is possible when people are standing that they are more likely to move. According to the study Oppezzo and Schwartz (2014), walking increases divergent thinking, even when walking inside on a treadmill. In contrast, Colzato et al. (2013) showed that physical exercise has no beneficial effects on divergent thinking. However, there is a difference between movement and exercise (Oppezzo and Schwartz, 2014). As a consequence of this result, it would be best to let people stand when they have to brainstorm. This not only increases creativity, but also increases the efficiency of the meeting by reducing the time with 34% (Bluedorn, Turban & Love, 1999). To promote standing meetings, it might be useful to reduce or remove furniture that affords sitting (Gibson, 1979). Moreover, it is best to do this for a limited period of time; otherwise people get tired and work performance will decrease (Hasegawa, et al., 2000).

The second hypothesis was: supine and passive sitting will improve convergent thinking. This hypothesis is rejected by the results. Research shows that lower levels of arousal is beneficial for insight problem solving (Beversdorf, et al, 1999), and being supine decreases the level of arousal (Thibault, et al, 2014). Therefore, a supine body position increases the performance on solving insight problems (Lipnicki & Byrne, 2005). However, it is possible that people are too aroused in the supine condition, since they mind find it exciting to lie down under a laptop stand. According to Aston-Jones and Cohen (2005) a high level of arousal decreases performance and disturbs exploitation. Furthermore, low levels of arousal impair performance. As discussed before people might have been tired during the study. Exploratory research shows that the circadian rhythm affects creativity but that it also depends on being a morning or evening type (Giampietro & Cavallera, 2007). When asking participants how energetic they were, moderate scores were shown. In addition, they commented on the supine condition that it was a surprising way of working, while others argued they could not work efficiently. Nevertheless, a diversifying experience can enhance creativity (Ritter, et al., 2012), but maybe more so when people do not have to write the ideas down, but can say it out loud (Knight and Baer, 2014). However, it is important to be aware of the fact that when people are tired and lying down, this body position will negatively affect the cognitive performance compared to sitting (Muehlhan, Marxen, Landsiedel, Malberg & Zaunseder, 2014).

One of the limitations of this study is that people were only for a short time period in a certain body position. Therefore, it can be suggested to do research on the effect of body position on creativity and problem solving when people are in the same body position for a longer time. This would then be more comparable to real life situations. Furthermore, the TMT shows very different

results on cognitive flexibility when changing the sample size. Accordingly, it can be suggested to replicate this experiment with more participants and perhaps in a more laboratory environment. Lastly, in this study the level of arousal is not measured explicitly. It can be suggested to study the level of arousal between the different body positions, to find out to what extent arousal and creativity are related. Moreover, in can be suggested to study to what extent an approach and avoidance body position (Friedman & Forster, 2002) are related to the adaptive gain theory of Aston-Jones and Cohen (2005).

Conclusion

To conclude, the results show that a standing body position affects divergent thinking, and active sitting affects cognitive flexibility. Supine and passive sitting do not show an effect on convergent thinking. Finally, stand up if you mind!

Practical implications for LEF future center

Since this thesis has been written to improve LEF sessions, some practical implications will be given. Most sessions are divided in a convergent thinking and divergent thinking component. The underlying mechanism of these components is cognitive flexibility. In this section there will be discussed how to use body position in an effective way.

According to the results of this study people are generating more ideas (divergent thinking) when they are standing. Therefore, it can be recommended to let people stand up, when brainstorming is part of a session. It cannot be said that standing has a negative or positive effect on convergent thinking, since no effects are shown in the insight problem solving task.
People do not elaborate on their ideas when supine. Accordingly, it can be recommended to use every body position except lying down when it is to purpose to expand on ideas. Standing would instead be a great alternative; according to Knight and Baer (2014) people elaborate more and share more knowledge when they are standing. However, comments from the participants showed that they find it surprising to lie down. This is in line with the findings of Ritter (2012) that showed that diversifying experiences enhances creativity.

Active sitting enhances cognitive flexibility. Active sitting is, for example, sitting on a stool. This is highly interesting for LEF since, their sedentary furniture mainly exists out of stools. Cognitive flexibility is the underlying mechanism of creativity, and in both stages; convergent and divergent thinking people will need this. Therefore it can be recommended to use stools when giving a creative session.

The following suggestions can be made for further research in LEF. Since arousal affects creativity and problem solving it might be interesting to invest in bracelets that can measure arousal. The facilitator could monitor this and act upon on the bodily changes that occur. Therefore, it can be suggested to do more research during real sessions. It would also be interesting to replicate this research with the same body positions, but during real sessions, where the group performance can be studied.

Conflict of interest statement

The author declares that this study was conducted in the absence of commercial or financial interests

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