Neural and cognitive mechanisms of creativity
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CHAPTER 7

Summary and Discussion

Summary of results

In this thesis, five empirical chapters investigated the functional and neuromodulatory basis of creativity, and tried to identify optimal conditions for divergent and convergent thinking. Since there is not a consensus in the scientific community on the definition of creativity, it is important to define the processes under study and the kind of task or test being applied to measure the concept of interest. In this thesis, two different thinking styles were considered as two different types of creativity: divergent and convergent thinking. The Alternative Uses Task (AUT) (Guilford, 1967) was employed to measure divergent thinking, and the Remote Associate Task (RAT) (Mednick, 1962) to measure convergent thinking.

Participants in this research were native Dutch speakers, so Dutch versions of creativity tests were needed. The AUT was easy to adapt and participants could easily be asked to write down as many possible uses for a common house hold item in their own language. However the RAT is different and its nature necessitated the development and validation of a Dutch version. In chapter 2, we have reported the development and validation of a 30-item Dutch version of the RAT, and Item Response Theory (IRT) was applied to generate a short, qualified, and valid 22-item out of 30-item test. The 30-item test was used in this thesis. The 22-item is reliable and very useful test to measure convergent thinking in research with time restrictions. The IRT approach was used to identify difficulty and discrimination parameters for each item as well, so one can choose items that fit the sample (for example: a group of people with low or high ability) and purpose of the research.

In chapter 3 we addressed whether individual measures of creativity would co-vary with the individual eye-blink rate (EBR), which may point to a connection between creativity and dopamine. The relationship between creativity, intelligence, and EBR—a clinical marker of brain dopamine function—was investigated. Results of three experiments with separate groups of subjects revealed that performance on an intelligence test (fluid intelligence) does not depend on brain dopamine function while creative performance does: results showed a negative correlation between convergent thinking and dopamine level and performance on divergent thinking test followed an invert U-shaped relation with the individual dopamine level.

The results of the experiments reported in chapter 3 were considered as the basic idea to run a mood induction experiment, which is reported in chapter 4. Results of a (positive or negative) mood induction experiment show that positive mood, when compared to negative mood, increased EBR and enhanced creative performance on a divergent thinking test. These results are consistent with previous research showing that positive mood enhances creative performance (Isen et al., 1987) and with the idea that the influence of positive mood on cognitive performance is due to increased dopamine levels (Ashby et at., 1999). Positive mood significantly increases EBR and improved flexibility in a divergent thinking task in people with low dopamine level. But there is a different scenario for people with medium (or high) level of dopamine, as the benefit of positive mood was very small and not significant. We conclude that the impact of positive mood on the performance in divergent thinking depends on an individual's dopamine level.

Chapter 5 presents the results of an experiment that investigated influence of performing a creativity test (divergent vs. convergent thinking) on mood state. Results revealed that performing divergent and convergent thinking tasks improved and impaired current mood, respectively. These results support the idea that mood and cognition are not just related, but that this relation is fully reciprocal (Bar, 2009; Gray, 2004; Gross, 2002; Salovey et al., 2002).

Performing divergent and convergent thinking tests establishes different cognitive control states. This idea was investigated in chapter 6 by seeking for after-effects of performing two creativity tests on five well-known cognitive tasks (1-Global-Local, 2-Stroop, 3-Simon, 4-Stop-Signal, 5-Attentional Blink). Results show that the control state induced by convergent thinking benefited performance in cognitive tasks that require top-down control and strong local competition between representations of relevant and irrelevant information (tasks 1-3); in contrast, divergent thinking induced a cognitive control state that enhances performance on tasks that benefit from less top-down control, such as the Attentional Blink task.

DISCUSSION

Brain dopamine function and performance on divergent and convergent thinking tasks

The studies of this thesis provide empirical evidence that creativity is not a homogeneous concept; rather it reflects the interplay of separate, dissociable processes such as convergent and divergent thinking (e.g., Guilford, 1967). The cognitive mechanism of these two processes is different, but not opposite as assumed by Eysenck (1993). Taken together, results of four studies presented in this thesis (chapters 3-6) show that convergent and divergent thinking are not necessarily opposite but they are not the same either, and optimal performance in different types of creativity tasks requires different conditions.

In chapter 3 we concluded that performance on divergent-thinking tasks varies as a function of individual dopamine level, where medium levels produce the best performance, while convergent thinking was best with low dopamine levels. This suggests that divergent and convergent thinking are both related to dopamine, but to different degrees and in different ways. It was observed that eye-blink rate was predicting creative performance, which provides strong support for approaches that relate creativity to dopamine (Ashby et al., 1999; Eysenck, 1993; Reuter et al., 2006). At the same time, however, the obtained dissociation calls for a more differentiated approach that distinguishes between convergent and divergent processes and allows for tapping different creativity-dopamine functions.

If positive mood increases the dopamine level, which also works as a mechanism to improve performance, as suggested by Ashby et al. (1999), then it seems difficult to account for the impact of mood-enhancing manipulations on performance. As we report in chapter 4, participants with a relatively low level of dopaminergic functioning are likely to benefit from better mood, whereas people with a relatively high level of dopaminergic functioning, such as individuals scoring high in psychoticism (Colzato, Slagter, van den Wildenberg & Hommel, 2009), may actually do not benefit of better mood. Depending on which part of the distribution happens to be more strongly represented in a given sample, the corresponding study may find a positive, negative, or no relationship between mood and the given performance measure. This may explain the seemingly confusing and contradictory relationship between mood and performance (Baas, De Dreu & Nijstad, 2008; Davis, 2009), especially if one considers that divergent and convergent thinking, often treated equivalent indicators of creativity, seem to relate to dopaminergic functioning in different ways. In fact, this thesis' observations (negative correlation between eye blink rate and performance in convergent thinking, chapter 3) suggest that increasing dopaminergic supply can be expected to actually hamper convergent thinking irrespective of the current level. If so, then mood is unlikely to affect convergent and divergent thinking in the same fashion, which is yet another reason as to make a distinction between the different aspects of human creativity.

Optimal brain dopamine function for cognition and creativity

Evidence from both physiological and behavioral studies suggests that normal cognitive performance occurs only within a limited range of dopamine receptor activation. Researchers have shown that cognitive functions are impaired when there is a decrease in dopamine functioning in the brain, as in Parkinson's disease, or with dopaminergic hyperproduction, as in case of schizophrenia (Gotham et al., 1988; Knable & Weinberger, 1997). Too little or too much dopamine receptor activation leads to deficient operation of the neural mechanisms that are required for optimum performance in divergent-thinking creativity tasks (due to a lack of facilitation or excessive inhibition, respectively) thus resulting in diminished cognitive performance. This suggests that optimal functioning of the prefrontal cortex needs an optimal level of dopamine as described by an inverted U-shape curve (Cools et al., 2001; Vijayraghavan et al., 2007).

It has been shown by a large number of studies that positive affect systematically influences performance on many cognitive tasks. The dopamine theory of positive affect (Ashby, 1999) accounts for many of these effects by assuming that positive affect is associated with increased brain dopamine levels. The theory accounts for influences of positive affect on olfaction, the consolidation of long-term (i.e., episodic) memories, working memory, and creative problem solving. It assumes that creative problem solving is improved, in part, because increased dopamine release in the anterior cingulate improves cognitive flexibility and facilitates the selection of cognitive perspective. This theory, along with research on the impact of positive affect on creative performance, helps us to better understand the mechanisms underlying the impact of dopamine on human creative performance.

It has been shown that during the course of normal aging, dopamine levels in the human brain decrease by 7% or 8% during each decade of life (e.g, Gabrieli, 1995; van Domburg & ten Donkelaar, 1991). Considering the relation between dopamine and cognitive performance, this raises the question whether cognitive flexibility and creative problem-solving also diminish with age. It is generally assumed that people become less flexible and more rigid as they get older. A large amount of research revealed that cognitive flexibility does decrease during normal aging (e.g., Collins & Tellier, 1994; Stankov, 1988), but we are not aware of any study that examined the effect of age on performance on creative problem solving specifically on divergent thinking (Alternative Uses Task) and convergent thinking (Remote Associate Task). If we consider flexibility as the main component of divergent thinking, we can assume that performance on this type of creativity task decreases with aging.

But at the individual level the actual picture might be more complex. Consider the results from chapter 3, where we demonstrated that optimal performance in divergent and convergent thinking is associated with medium and low levels of dopamine respectively. If we accept that aging is associated with a decrease of dopamine, we can assume that people with a high level of dopamine might be more creative as they get older in both divergent and convergent thinking (Figure 1, black-arrows). It is possible that a similar scenario applies to other cognitive tasks that relate to brain dopamine function in an inverted U-shaped fashion, such as working memory tasks. In contrast to high-level dopamine individuals, it is likely that aging has no advantage or is even harmful for creative performance for people with low dopamine levels. More research is needed to examine this possibility in order to fully understand the role of interaction of aging and dopamine on creative performance.

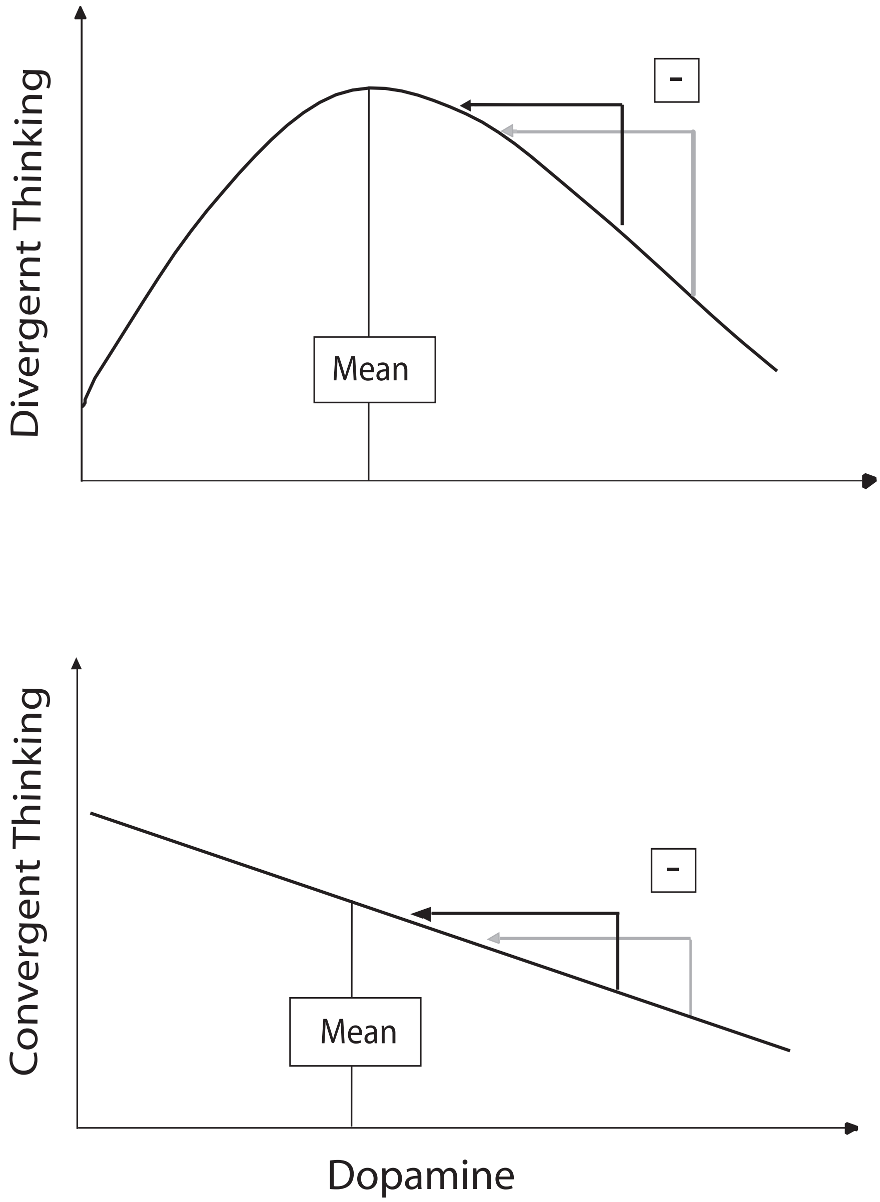

Figure 1: Hypothetical functions relating performance in divergent and convergent thinking to the individual dopamine level. Estimates of group means are taken from Akbari Chermahini & Hommel (2010). Note that, depending on the base level of dopamine, an age-related decrease in dopamine might be beneficial for divergent and convergent thinking tasks for some clinical populations (e.g., schizophrenic; gray-arrows) and in non-clinical population for individuals with high level of dopamine (black-arrows).

Moving to clinical populations, our approach raises interesting questions regarding the impact of aging on performance. For instance, it predicts that people who suffer from too high levels of dopamine (such as in schizophrenia) should actually benefit from aging—due to the aging-induced decease in dopamine levels (Figure 1, gray-arrows). These and related considerations encourage novel questions and lines of research, which we believe can further increase our understanding of creative performance and the cognitive mechanism involved in an optimum level of creativity.

Implications of the results of this thesis might also be important for education and business. If we consider creativity the fountainhead of human civilization, all progress and innovation depends on our ability to change existing thinking patterns, break with the present, and build something new. So, it is no surprise if we see managers seeking to boost creativity in their employees, school-teachers desiring to elevate creative problem solving among their pupils, and parents trying to bring out the artistic talent in their children. Based on the results of our research, we assume they can get better results if their training practice and interventions consider individual differences in dopaminergic functioning as well as the type of creativity that is intended to be enhanced. This certainly holds for the relationship between the effect of mood and individual dopamine levels in the context of performance in divergent thinking—as investigated in this thesis. Whether it also holds for the effect of mood on convergent thinking remains to be investigated.

Creativity and mood: reciprocal effects

In chapter 5 it was found that carrying out a task that requires creative thinking affects people's mood. Moreover, divergent and convergent thinking impact mood in opposite ways: while divergent thinking improves one's mood convergent thinking lowers it. This provides considerable support for the idea that mood and cognition are not just related, but that the relation is fully reciprocal (Bar, 2009; Gray, 2004; Gross, 2002; Salovey et al., 2002). This dissociation is consistent with Akbari Chermahini and Hommel’s (2010) observation that divergent and convergent thinking are related to one's dopamine level—the common currency that apparently mediates the interaction—and that these two relationships follow rather different functions. Performing divergent thinking and convergent thinking tasks evoke different, apparently even opposite stereotypical reactions which do not seem to reflect individual performance and, thus, objective task difficulty. However, actually carrying out the task and the related thinking operations further boosts the task-specific mood changes to a degree that goes beyond possible stereotypical responses. In a broader perspective, this research's findings demonstrate uncertainty principle (Heisenberg, 1927), according to which the act of measurement can change what is being measured. As it seems, engaging in a creativity task creates a mood swing in the direction that facilitates performance in that particular task. It can be conclude that mood and cognition are not just related, but that this relation is fully reciprocal.

This fits with the theoretical considerations of Bar (2009) that there is a direct reciprocal relation between the cortical activation of associations and mood regulation, whereby positive mood promotes associative processing, and associative processing promotes positive mood. The activation of associations might be beneficial for improving mood because associations afford the generation of predictions, and prediction minimize uncertainty, thus reducing anxiety and stress, which are both concomitants of mood disorder. The second mood-related benefit of broad associative activation is that associations prevent persistent rumination, another hallmark of mood disorder, by distracting the thought process away from dwelling on a narrow, negative theme. Broad associative activation helps gain a broader perspective. This calls for a distinction between narrow and broad associative activations. Narrow associative thinking, or rumination, refers to associations that surround a narrow focus (Figure 2a). Broad associative activations, by contrast, active association that make thought processes advance from one context to another smoothly (Figure 2b).

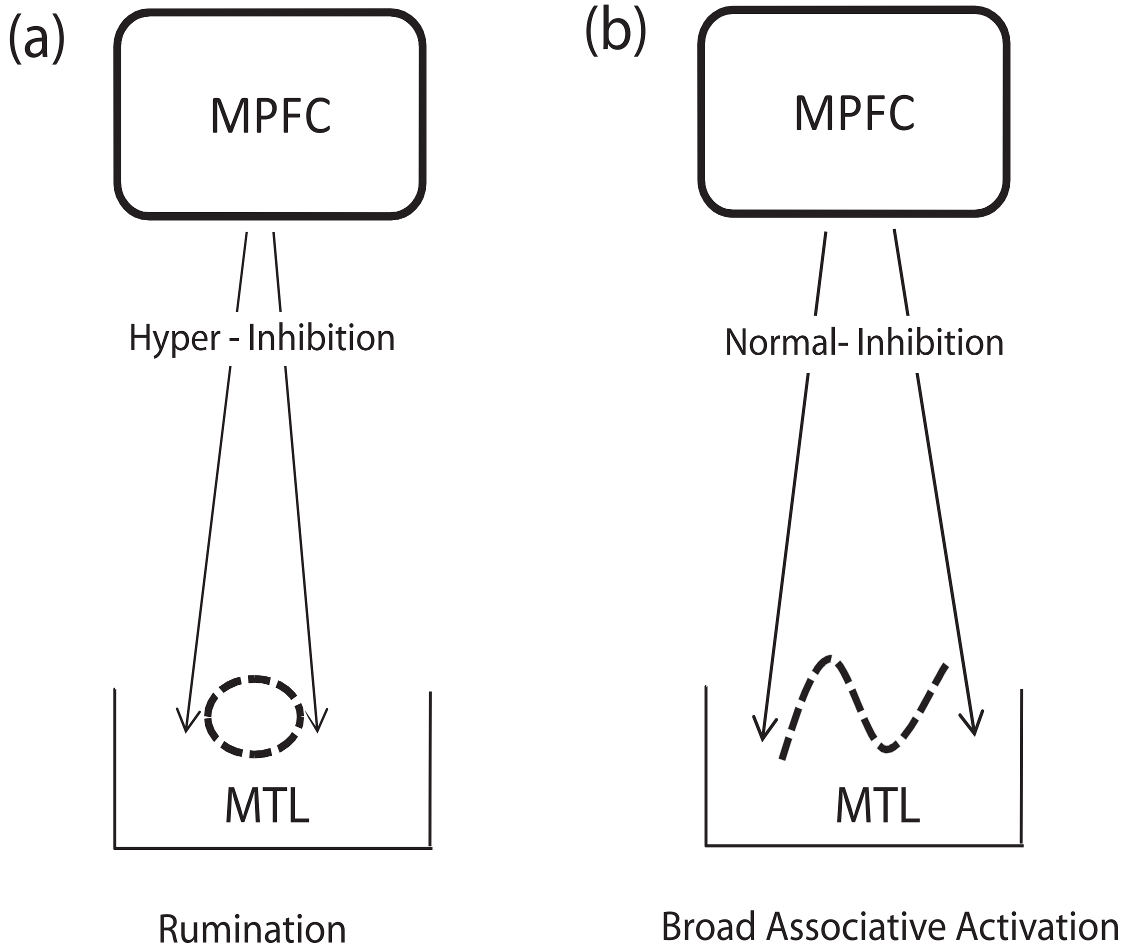

Figure 2: Rumination versus broadly associative thinking. (a) The thought pattern typical of mood disorder involves rumination around a narrow focus. Even if this thought pattern is associative, it is limited in scope. Such constrained thought is proposed here to stem from hyper-inhibition from the MPFC (medial prefrontal cortex) to the MTL (medial temporal lobe). (b) The thought pattern in the brain of individuals without mood disorders is characterized by a broadly associative activation that, although still affected by inhibition signals (for functional guidance), can seamlessly disengage from one focus and advance to another. (Reproduced from Bar, 2009; *Trends in Cognitive Science*. 13)

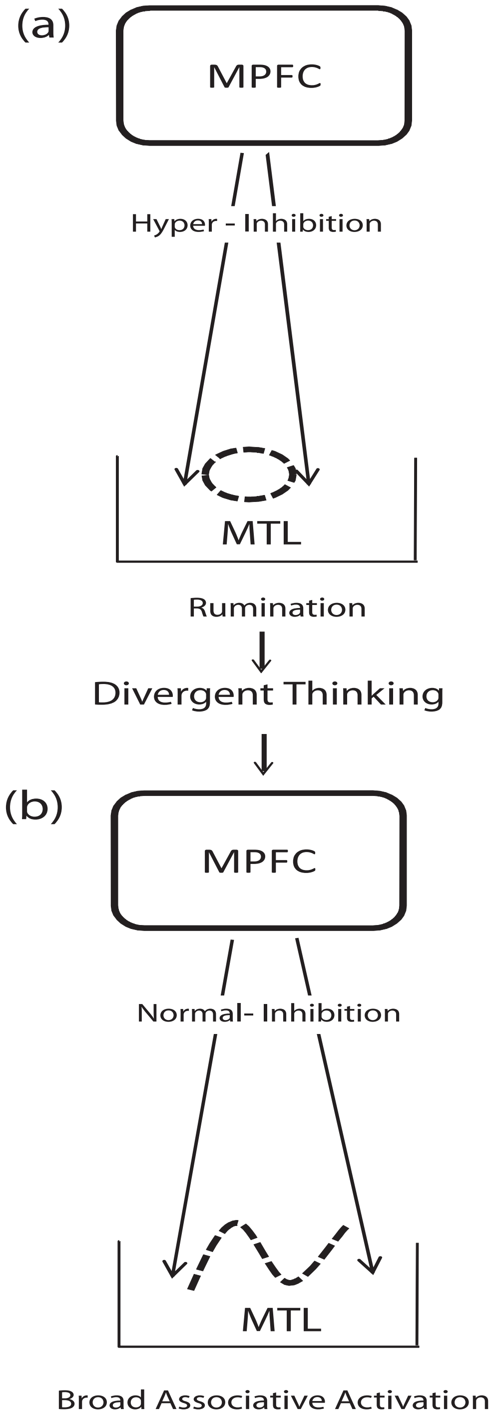

Figure 3: Performing a divergent thinking task might improve mood and change the associative activation from narrow representation (a) to broad representation (b).

As we mentioned earlier, results from chapter 5 show that performing a divergent thinking task elevates mood. This result can be explained by the assumption that broad associative activation improves mood. This finding has the practical implication that performing a divergent thinking task might be a non-invasive method for treating mood disorders, especially in people who suffer from rumination (negative narrow scope of attention) that is associated with depression. The training and restructuring of the ability for broad associative thinking can elicit improvements that range from structure modification to mood and behavior (Figure 3). Future research needs to investigate whether performing a divergent thinking task can be useful to change the narrow focus and rumination in individuals with depression to broad associative activation to at least some degree, and improve their mood.

Creativity and cognitive control

Convergent and divergent thinking apparently induce different cognitive control states in individuals and support performance of individuals in different cognitive tasks in different ways. The after-effect of performing divergent and convergent thinking tasks on 5 cognitive tasks (Global-Local, Stroop, Simon, Stop-Signal, Attentional Blink) was investigated and reported in chapter 6. Results from five experiments revealed that convergent thinking benefited performance in the tasks that are suspected to induce conflict between perceptual interpretations (Global-Local task), semantic (semantic-Stroop task), and response codes (Simon task) by establishing a relatively strong top-down cognitive-control state and also reduce various sorts of cognitive conflict. Cognitive control induced by convergent thinking was not beneficial for all cognitive tasks. In contrast divergent thinking induces cognitive control state and benefits tasks that apply less top-down control (such as Attentional Blink task).

The findings suggest a scenario according to which convergent and divergent thinking are associated with specific control states that people can apparently establish when needed. Nevertheless, this does not rule out the possibility that some individuals are more able, proficient, or practiced in establishing one or another of these states. In that sense, the findings do not rule out the possibility that some individuals are, or at least can be more creative than others—the trait account of creativity. Thereby it is suggested that creativity is a matter of intra-individual variability where the same person can be more or less creative.

The five studies presented in chapters 2-6 illuminate that human creativity is not a unitary concept and is consistent with conclusions from earlier research that creativity tasks differ substantially in their sensitivity for particular aspects of creative performance (Baas, De Dreu, & Nijstad, 2008). The findings provide strong evidence that divergent-thinking and convergent-thinking tasks are two different types of tasks to measure two types of creativity and that they do not measure the same thing. It can be said that divergent and convergent thinking are ideal types, and not mutually exclusive. Both convergent and divergent thinking are needed for any truly creative activity; latter presumably more in leading brainstorming phase that considers all possible options and former more in the following phase in which the preferred option is further thought through and worked out.

Taken together, the results of the five empirical chapter of this thesis indicate that creativity, an important skill that is often thought of as a stable characteristic of people, can be facilitated by a transient pleasant affective state. Moreover, the affective state sufficient to do this can be induced subtly, by small everyday events. This suggests that creativity can be fostered by appropriate modification of the physical or interpersonal environment. But one should be aware that not everybody benefited from good mood.

The most important implication of the results in this thesis is for future research on individual differences and creative performance as well as on mood and creativity research. Furthermore, by identifying cognitive mechanism and the basic principles of creativity, researchers might be able to enhance this process better in the future, with potentially enormous benefits for society.

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