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ORIGINAL ARTICLE

Food for creativity: tyrosine promotes deep thinking

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Abstract Anecdotal evidence suggests that creative people sometimes use food to overcome mental blocks and lack of inspiration, but empirical support for this possibility is still lacking. In this study, we investigated whether creativity in convergent- and divergent-thinking tasks is promoted by the food supplement L-Tyrosine (TYR)—a biochemical precursor of dopamine, which is assumed to drive cognitive control and creativity. We found no evidence for an impact of TYR on divergent thinking ("brainstorming") but it did promote convergent ("deep") thinking. As convergent thinking arguably requires more cognitive top-down control, this finding suggests that TYR can facilitate control-hungry creative operations. Hence, the food we eat may affect the way we think.

Introduction

Anecdotal evidence suggests that creative people sometimes use food to overcome mental blocks and to get deeper into a problem. Steve Jobs, arguably one of the most creative minds of our time, often referred to his diet (which was based on apples and raw carrots) as the foundation of his success. Given that these foods are high in the amino acid tyrosine, the biochemical precursor of dopamine (DA) and norepinephrine (NE), this makes a lot of sense but empirical studies on the connection between food and creativity are lacking. Here, for the first time, we tested whether creativity is promoted by administering the food supplement L-Tyrosine (TYR). TYR supplementation and TYR-containing diets are known to increase plasma TYR and enhance brain catecholamine release (Acworth, During, Wurtman, 1988; During, Acworth, Wurtman, 1988; see Deijen, 2005, for a comprehensive review), which in turn has been argued to fuel cognitive control in general (Cools, 2006) and creativity in particular (Akbari Chermahini & Hommel, 2010).

Given the lack of a widely accepted definition of creativity (Runco, 2007), we did not try addressing creativity as a whole but focused on what Guilford (1967) considered the main components of creative performance: divergent and convergent thinking–components that are rather transparent at the process level and thus easier to investigate. More concretely, we investigated the link between TYR supplementation and two creativity tasks tapping into convergent and divergent thinking in healthy adults, who were exposed to an oral dose of either TYR or a neutral placebo. Potential changes in physiology due to TYR supplementation were measured by collecting heart rate and blood pressure. Divergent thinking is taken to represent a style of thinking that allows many new ideas being generated, in a context where more than one solution is correct—like a brainstorming session. Guilford's (1967) Alternate Uses Task (AUT) to assess the productivity of divergent thinking follows the same scenario: participants are presented with a particular object, such as a pen, and they are to generate as many possible uses of this object as possible. Convergent thinking, in turn, is considered a process of generating one possible solution to a particular problem. It emphasizes speed and relies on high accuracy

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and logic. Mednick's (1962) Remote Associates Task (RAT) that aims to assess convergent thinking fits with this profile: participants are presented with three unrelated words, such as "time", "hair", and "stretch", and are to identify the common associate ("long").

Note that AUT and RAT are unlikely to represent non-overlapping, process-pure measures of the underlying cognitive functions (Hommel, 2012). While the RAT clearly involves more top-down constraints on the cognitive search process than the AUT, it still has a search component that requires flexibly moving from one memory trace to the next; and while the AUT clearly involves more extensive and less constrained cognitive search than the RAT, it still involves some constraints. And yet, the convergent component is clearly more important in the RAT than it is in the AUT, while the opposite holds for the divergent component. It is these relative differences that we based our hypotheses on. Fortunately, there is evidence that such relative differences are sufficiently diagnostic, as performance on the AUT and the RAT are uncorrelated (Akbari Chermahini & Hommel, 2010), differently affected by the same experimental manipulations (Hommel, Akbari Chermahini, van den Wildenberg & Colzato, 2014) and by learning the same skills (Hommel, Colzato, Fischer & Christoffels, 2011), and performing the AUT and the RAT has different, sometimes even opposite effects on other affective and cognitive operations (Akbari Chermahini & Hommel, 2012a; Fischer & Hommel, 2012)—all of which supports Guilford's (1967) suggestion that convergent and divergent thinking represent different, separable components of human creativity. This dissociation of human creativity seems to correspond to the Dual Pathway to Creativity model (De Dreu, Nijstad, Baas, Wolsink, & Roskes, 2012; Nijstad, de Dreu, Rietzschel & Baas, 2010) suggesting that creative performance originates from the balance between cognitive flexibility and cognitive persistence—two dissociable cognitive control functions (De Dreu et al., 2012; Goschke, 2013).

We (Colzato, Ozturk & Hommel, 2012; Fischer & Hommel, 2012; Hommel, 2012) have argued that divergent thinking (as assessed by the AUT) is likely to require, or at least benefit from a cognitive-control state that provides a minimum of top-down bias and local competition, so that the individual can easily and quickly "jump" from one thought to the other in an only weakly guided fashion. Hence, divergent thinking should rely on weak top-down control, given that it implies a broad, loosely defined search space in order to activate many items that satisfy the often relatively soft criteria. In contrast, convergent thinking (as assessed by the RAT) is likely to require, or benefit from more cognitive control and, as a consequence, stronger top-down bias and more pronounced local competition between alternative representations. Hence, convergent thinking should rely on strong top-down control because it represents the tightly constrained search of very few or just one item. Consistent with these considerations, we observed that creativity-unrelated cognitive tasks requiring weak top-down control benefit from being interleaved with performing the AUT (as compared to the RAT) while tasks requiring strong top-down control benefit from being interleaved with performing the RAT (as compared to the AUT; Hommel et al., 2014).

If we consider that cognitive control emerges from the interplay between the prefrontal cortex and the striatum, which both are driven by DA (Cools, 2006; Cools & D'Esposito, 2010), one would expect that more control-hungry thinking processes are more strongly affected by TYR—the DA precursor. As we have argued that strong cognitive control is more important for convergent thinking than it is for divergent thinking, one would expect performance on the RAT to be more affected by TYR than performance on the AUT.

Method

Participants

Thirty-two healthy adults (mean age = 19.4; 8 male, 24 female; mean body mass index = 22.2, range 18.3–26.4), native Dutch speakers, with no cardiac, hepatic, renal, neurological or psychiatric disorders, personal or family history of depression, migraine and medication or drug use participated in the experiment. Following Colzato, Jongkees, Sellaro & Hommel (2013), Colzato, Jongkees, Sellaro, van den Wildenberg, & Hommel (2014), in separate sessions participants were exposed to either an oral dose (powder) of 2.0 g of L-Tyrosine (TYR) (supplied by Bulk Powders Ltd.) or of 2.0 g of microcrystalline cellulose (Sigma-Aldrich Co. LLC), a neutral placebo, dissolved in 400 ml of orange juice. TYR and placebo doses were administered in two different experimental sessions separated by 7 days (±1 day). A double blind, placebo-controlled, randomized cross-over design with counterbalancing of the order of conditions was used to avoid expectancy effects (Meyer & Quenzer, 2005). None of the participants was able to detect any taste difference between the placebo and TYR sessions.

Following Markus, Firk, Gerhardt, Kloek, & Smolders (2008), we tested only women taking oral contraceptives, and we tested them when they actually used the contraception pill. The reason was that variation in hormone levels (such as throughout the menstrual cycle) has considerable effects on cognitive functioning (for a recent review, see Farage, Osborn, & MacLean, 2008) and on creativity in particular. For instance, Krug, Stamm, Pietrowsk, Fehm, & Born (1994) tested women throughout their menstrual cycle and found that creativity (as measured by six different divergent thinking tests) improved when concentrations of estrogen and luteinizing hormone were highest (such as right before the ovulation). As women taking oral contraceptives do not show this variation (Krug et al. 1994), we restricted our sample to participants meeting this criterion.

On each experimental morning, participants arrived at the laboratory at 9:30 a.m. Participants had been instructed to fast overnight; only water or tea without sugar was permitted. In addition, subjects were not allowed to use any kind of drugs before and during the experiment or to drink alcohol the day before their participation and arrival at the laboratory. Written informed consent was obtained from all subjects; the protocol and the remuneration arrangements of 15 euro were approved by the local ethical committee (Leiden University, Institute for Psychological Research).

Procedure

All participants were tested individually in both experimental sessions. Upon arrival, participants were asked to rate their mood on a 9 × 9 Pleasure × Arousal grid (Russell, Weis, & Mendelsohn, 1989) with values ranging from −4 to 4. Heart rate (HR) and systolic and diastolic blood pressure (SBP and DPB) were collected from the non-dominant arm with an OSZ 3 Automatic Digital Electronic Wrist Blood Pressure Monitor (Spiedel & Keller). One hour following the administration of TYR (corresponding to the beginning of the 1 h-peak of the plasma concentration; Glaeser, Melamed, Growdon, & Wurtman 1979) or placebo, participants again rated their mood before having HR, SBP and DBP measured for the second time. Afterwards, participants were asked to perform the creativity tasks: the remote associates task (RAT; based on Mednick, 1962, and translated into Dutch) and the alternate uses task (AUT: Guilford, 1967). The order of the creativity tasks was counterbalanced between participants by means of a Latin square design. No other cognitive tasks were administered in this study.

After the creativity tasks, participants again rated their mood before having HR, SBP and DBP measured for the third time.

Remote associates task (convergent thinking)

In this task, participants are presented with three unrelated words (such as "time", "hair", and "stretch") and asked to find a common associate ("long"). Our Dutch version comprised of 30 previously validated items (Akbari Chermahini et al., 2012). In each of the two sessions, participants completed 15 different items, which were selected and balanced according to the item difficulty scores reported by Akbari Chermahini et al. (2012). The two resulting versions were counterbalanced across participants and conditions.

Alternate uses task (divergent thinking)

In this task, participants were asked to list as many possible uses for four common household items ("pen", "towel", "bottle", "brick"). In the two sessions, participants completed two of these items. The results can be scored in several ways with flexibility, the number of different categories used being the theoretically most transparent and the empirically most consistent and reliable score (Akbari Chermahini et al., 2012). In the case of the item "pen," "writing an essay," and "writing a letter" would fall into the same category, but "drumming on the table" would fall into a different category. Here we considered four scores:

Flexibility The number of different categories used.

Originality Each response is compared to the total amount of responses from all of the subjects. Responses that were given by only 5 % of the group count as unusual (1 point) and responses given by only 1 % of them count as unique (2 points).

Fluency The total of all responses.

Elaboration The amount of detail (e.g., "a door stop" counts 0, whereas "a door stop to prevent a door slamming shut in a strong wind" counts 2 (1 point for explanation of door slamming and another for further detail about the wind).

Statistical analysis

HR, BPD, BPS, mood and arousal were analyzed separately by means of repeated-measures analyses of variance (ANOVAs) with condition (Placebo vs. TYR) and effect of time (first vs. second vs. third measurement) as within-subjects factor. The five creativity measures (from the two tasks) were extracted for each participant: flexibility, originality, fluency, and elaboration scores from the AUT, and the number of correct items from the RAT. All four AUT measures were scored by two independent raters (Cronbach's alpha = 0.94). All measures were analyzed separately by means of repeated-measures ANOVAs with condition (Placebo vs. Tyrosine) as within-subjects factor. BMI was added as covariate to correct for the wide range included in this study (18.3–26.4). Effect magnitudes were assessed by calculating partial Eta squared (η_p^2) and Cohen's *d* (Cohen, 1988) for repeated measures ANOVAs. A significance level of $p < 0.05$ was adopted for all tests.

Table 1 Mean and standard deviations (SD) for originality, fluency, flexibility, and elaboration scores from the Alternate Uses Task (AUT), the number of correct items from the Remote Associates Task (RAT), and perceived mood ratings as a function of TYR and Placebo

Session	TYR	Placebo
AUT		
Elaboration	1.1 (1.6)	0.8 (1.0)
Fluency	15.4 (5.4)	15.8 (5.8)
Flexibility	10.8 (3.1)	11.0 (3.5)
Originality	8.7 (6.3)	9.1 (5.6)
RAT*	5.8 (2.4)	4.7 (2.6)

* $p < 0.01$ (significant group difference)

Results

Creativity tasks

In general, performance in the AUT and RAT was good and comparable to performance in other studies without nutritional manipulations (e.g., Akbari Chermahini & Hommel, 2010). As expected, using BMI as covariate, participants performed better in convergent thinking in the TYR condition (5.8, SD = 2.3) than in the placebo condition (4.7, SD = 2.2), $F(1,30) = 11.44$, $p = 0.002$, MSE = 6.969, $\eta_p^2 = 0.30$, $d = 0.5$. In contrast to the RAT findings, the four scores of the AUT, flexibility, originality, fluency and elaboration were not modulated by condition, F's < 1, see Table 1.

Physiological and mood measurements

In line with previous studies (Colzato et al., 2013; Colzato et al., 2014), ANOVAs revealed that HR (76 vs. 75 vs. 67 and 79 vs. 73 vs. 66 after placebo and TYR, respectively), BPD (73 vs. 70 vs. 70 and 73 vs. 69 vs. 70 after placebo and TYR), BPS (120 vs. 119 vs. 116 and 117 vs. 116 vs. 111 after placebo and TYR), mood (1.2 vs. 1.2 vs. 1.3 and 1.1 vs. 1.4 vs. 1.5 after placebo and TYR), and arousal (−0.5 vs. 0.5 vs. 0.5 and −0.2 vs. 0.9 vs. 0.9 after placebo and TYR) did not significantly change after the intake of TYR, F's < 1.

Discussion

The present study was the first to test whether TYR supplementation promotes components of human creativity. We argued that TYR supplementation, and the resulting boost in DA, should be more beneficial for control-hungry processes. As there are reasons to assume that convergent thinking is more control-hungry than divergent thinking is (Colzato et al., 2012; Fischer & Hommel, 2012; Hommel, 2012), we expected convergent thinking to be more affected. Consistent with this expectation, TYR supplementation had an impact on RAT performance but we found no evidence for an impact of TYR on divergent thinking (as indexed by the AUT), which is the first demonstration that human creativity can be enhanced by dopamine-related food supplements. It might be interesting to consider that more control-hungry tasks lead to more or faster "ego-depletion"—the hypothesized exhaustion of limited cognitive control resources (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Inzlicht & Schmeichel, 2012). Given the present demonstration that performance in a control-hungry task can be improved by TYR, TYR might be seen as an effective "ego-repletor". Consistent with this possibility, we were able to demonstrate that TYR supplementation promotes stopping overt responses (Colzato et al., 2014) and WM updating (Colzato et al., 2013), two processes that are commonly considered to draw considerably on cognitive-control resources.

Even though TYR is the precursor of both DA and NE, we are confident that it was DA that was responsible for our results. In an unpublished study with Sander Nieuwenhuis, we had participants to perform on the AUT and RAT after intake of an oral dose of 80 mg propranolol (beta blocker) or placebo in a randomized, double-blind, counterbalanced cross-over design. We failed to find any significant effects of propanolol on both divergent and convergent thinking. Moreover, one may argue that elevated NE levels resulted in better attention after TYR supplementation, and that this might have improved performance on more effortful RAT task. However, this reasoning is not supported by the finding that the α2 adrenoceptor agonist clonidine (150 µg, oral dose) has no effect on temporal or spatial attention (Nieuwenhuis, Van Nieuwpoort, Veltman & Drent, 2007).

Other previous studies in humans have found blood pressure to decrease after TYR administration. However, in one study the high dose of 100 mg/kg TYR (Deijen & Orlebeke, 1994) was used and in the other study the dose of 2 g was administered at long-term (every day for 6 days) (Deijen, Wientjes, Vullinghs, Cloin & Langefeld, 1999). It may be possible that TYR has a beneficial effect on blood pressure only when repeatedly administered or at higher dose than 2 g.

More research is needed to replicate, clarify, and extend our results. For one, it needs to be seen whether and to which degree our findings are restricted to the verbal creativity tasks we employed or whether they generalize to nonverbal kinds of creativity. For another, future studies need to take individual differences into account. Individual differences in DA production do not only predict individual performance in creativity tasks (Akbari Chermahini & Hommel, 2010) but also the degree to which individuals benefit from creativity "enhancers" (Akbari Chermahini & Hommel, 2012b). More specifically, previous studies have shown individual differences in the reactivity to TYR (Deijen and Orlebeke, 1994; Shurtleff et al. 1994; Mahoney et al. 2007), suggesting that preexisting neurodevelopmental factors (such as genetic variability related to levels of DA) affect the degree to which individuals can benefit from TYR supplementation. A limitation of our study is the lacking of plasma TYR levels measurements. In a replication of our study, it would be important to correlate those assessments with convergent thinking performance.

To summarize, our results support the materialist approach that "you are what you eat" (Feuerbach, 1862)—the idea that the food one eats has a bearing on one's state of mind. The food we eat may thus act as a cognitive enhancer that modulates the way we deal with the physical world, or at least with how deeply we can think. In particular, the supplementation of TYR, or TYR-containing diets, may promote convergent thinking in inexpensive, efficient, and healthy ways, thus supporting the creative process that Steve Jobs was such a superior exponent of.

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