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# Creativity training enhances goal-directed attention and information processing

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ABSTRACT

Studies suggest that individuals with greater creative potential have enhanced executive function. Here we tested the hypothesis that a creativity training intervention would increase both low and high-level executive functions. Fifteen participants completed a 5-week creative capacity building program (CCBP) and 15 participants completed a control intervention consisting of a parallel 5-week language capacity building training program (LCBP). Goal-directed attention and processing speed were measured with the Delis–Kaplan Executive Function System (D-KEFS) color–word interference test. Results revealed higher scores post-training associated with CCBP compared to LCBP on the primary D-KEFS measure of combined completion time for color-naming and word-reading conditions, and the primary contrast measure of combined completion time for color-naming and word-reading compared to completion time for inhibition switching. Relative to LCBP, CCBP leads to improvement performance on measures reflecting lower-level executive functions (goal-directed attention and information processing) as opposed to higher-level executive functions, which showed no between-group differences.



## 1. Introduction

Creativity has been associated with general intelligence, divergent thinking, dimensions of personality, and increasingly, executive functions (Batey & Furnham, 2006; Benedek, Franz, Heene, & Neubauer, 2012; Furnham & Bachtiar, 2008; Guilford, 1988; Hocevar, 1980; Kaufman, Kaufman, & Lichtenberger, 2011; Kettner, Guilford, & Christensen, 1959; Kim, 2008;

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Silvia, 2008). Broadly defined, "lower-level" executive functions include attention and processing speed, while "higher-level" executive functions include inhibition, cognitive flexibility, fluency, working memory, and organization of thoughts and behaviors (Dempster & Corkill, 1999). To date, the relationship between executive functions and creativity has been studied cross-sectionally (i.e., at one specific point in time). In this paper, we examine the longitudinal changes in executive functioning associated with targeted creativity training designed to enhance creative capacity in healthy adults.

While research has examined whether an individual's creative capacity can be augmented with training (Scott, Leritz, & Mumford, 2004; Torrance, 1979; Torrance & Safter, 1999), these attempts to stimulate or increase creativity have mostly been done in children and adolescents in scholastic settings (Baer, 1996; Clapham, 1997; Glover & Gary, 1976; Scott et al., 2004). Scott et al. (2004) review of seventy creativity-training based intervention studies found training-related changes in younger participants with moderate to large effect sizes across modality, setting, and population. Although a large set of studies show efficacy of targeted training to enhance creative capacity in children, some work has also shown that gains accrued from such training do not transfer well across domains (Baer, 1988, 1996, 2009) and, thus, provide contrasting evidence for domain general constructs of creative capacity enhancement (Baer, 2012). Few studies have investigated the efficacy of domain-specific creativity training in adults (Solomon, 1990), and no such interventions have included measures of executive functioning in adults. We utilized a design-thinking based creativity-training intervention to examine potential changes in lower- and higher-level executive functioning. Investigating whether creative potential is associated with cognitive change will deepen our understanding of brain plasticity and holds potential for unraveling alternative interventions to treat executive dysfunctions associated with neurological and psychiatric conditions.

Creativity has been previously defined as a behavior or product that is both novel and appropriately useful (Sternberg & Lubart, 1996). More specifically, creativity has been described as, "the process of becoming sensitive to problems, deficiencies or gaps in knowledge, missing elements, disharmonies, and so on; identifying the difficulty searching for solutions, making guesses, or formulating hypotheses about the deficiencies; testing and retesting these hypotheses and possibly modifying and retesting them; and finally communicating the results" (Torrance, 1965). Recently, domain-specific constructs of creativity have also been posited (Baer, 2011, 2012), with various categories of creative domains being offered (Agars, Baer, & Kaufman, 2005; Baer & Kaufman, 2005; Ivcevic & Mayer, 2009). For the purpose of this study, we define creativity as "a state of being and adaptation of personal skill sets that enables an individual to synthesize novel connections and express meaningful outcomes" (Hawthorne et al., 2013).

People who obtain higher scores on measures of creativity (henceforth referred to as "creative people" for brevity) exhibit strengths in both lower- and higher-level executive functions. Specifically, creative people show enhanced goal-directed attention skills, an example of low-level executive functioning (Ansburg & Hill, 2003; Zabelina & Beeman, 2013). Creative people have shorter reaction times on tasks with little cognitive interference and longer reaction times on tasks with greater cognitive interference, indicating enhanced differential lower- and higher-level executive functioning, depending upon task demands (Dorfman, Martindale, Gassimova, & Vartanian, 2008; Kwiatkowski, Vartanian, & Martindale, 1999; Vartanian, Martindale, & Kwiatkowski, 2007). On the other hand, one study found wider breadth of attention correlated with creative performance, exposure to attention narrowing stimuli diminished creative performance (Kasof, 1997). Creative people also show greater cognitive control on the Stroop task (Groborz & Necka, 2003). Gilhooly, Fioratou, Anthony, and Wynn (2007) demonstrated that greater executive capacity of strategy switching, a higher-level executive function skill, was associated with increased creativity. They found that performance on the letter fluency "executive loading task" predicted fluent production of new uses on the alternate uses task, a measure of creativity (Guilford, 1967). Production of familiar uses from long-term memory, which requires less involvement of higher-level executive function than the letter fluency task, was not associated with performance on the alternate uses task. Similarly, Nusbaum and Silvia (2011) found that increased executive switching on a divergent thinking task mediated the effect of fluid intelligence measures of creativity. Creative people also show enhanced performance on the specific conditions of the Stroop color word test assessing inhibition and cognitive flexibility, which are higher-level executive functions (Golden, 1975; Groborz & Necka, 2003; Zabelina & Robinson, 2010).

Thus, there is evidence from cross-sectional data that creativity is related to executive functioning skills or ability. The question of central interest to the present study was whether a creativity training intervention would increase lower- and higher-level executive functioning. We sought to address this question with a 5-week, random assignment, parallel-group design where participants received either creativity training or a control language training. The creativity training was domain-general and was built upon several theories ranging from problem solving skills, affective processing, motivational aspects, and creative confidence building, and was part of a larger project investigating the neural correlates of creativity (Hawthorne et al., 2013). In a companion paper in the same Journal, we have provided more details about the training (Kienitz et al., 2014). Using the Torrance Test of Creativity, figural version (TTCT-F) (Torrance, 1981), a standardized divergent thinking measure of creativity, we found moderate to large effect size increases in TTCT-F average, elaboration, and resistance to closure scores, pointing to a wider synthesis of ideas after training. We thus predicted that this creativity training would also be associated with enhancement in lower-level executive abilities, specifically of goal-directed attention and processing speed, as well as higher-level executive abilities, specifically with respect to fluency, inhibition, and flexibility.

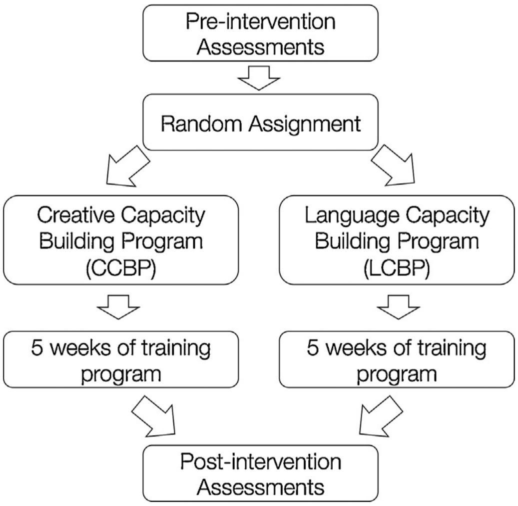


**Fig. 1.** Study design flowchart.

## 2. Methods

### 2.1. Participants

Pre-intervention data were collected before the participants were randomly assigned to either a 5-week creative capacity building program (CCBP) or a language capacity building program (LCBP) of same duration. All participants were reassessed after the 5-week training course. See Fig. 1 for a visual representation of the study design. Thirty-six adults, 19–39 years of age, completed the pre-intervention assessment and 30 completed the post-intervention assessment (15 in the CCBP group and 15 in the LCBP group). Demographics for the 30 participants who completed both time points are shown in Table 1. Groups did not differ on age, sex, IQ, and socio-economic status. Of the initial 36 participants, 2 withdrew participation before the first CCBP and LCBP session, 1 participant was excluded due to lack of class participation, 1 participant was excluded due to use of prescription antidepressants, and 2 participants completed the training program but not the assessments due to time constraints.

Data for this study were collected as part of a larger experimental protocol examining the cognitive, behavioral, personality, and neural correlates of creativity in normal healthy adults, as well as the effects of a creativity intervention on measures of creative performance (Hawthorne et al., 2013). Participants met the inclusion criteria for the study if they were (a) available for the entire duration of the study, (b) did not speak Mandarin, (c) were not enrolled in classes at the Design Institute and had not taken such classes in the past year, and (d) could undergo a magnetic resonance imagining (MRI) scan of the head. Participants were excluded from the study if they self-reported a current or past history of psychiatric or neurological conditions that had lead them to consult a medical professional, or metallic devices or implants in the head or body that are contraindicated for MRI. All participants were right-handed. We recruited participants by sending out flyers via emails, message boards, listservs, and word of mouth. Participants were recruited on or around the University campus and surrounding areas. The University's research ethics board approved this study.

**Table 1**
Participant data.

| Variable | Total ($N = 30$) | CCBP ($N = 15$) | LCBP ($N = 15$) | $t$ | Sig. (2-tailed)* |
|---|---|---|---|---|---|
| AGE, mean (S.D.) | 28.43 (5.42) | 28.27 (5.46) | 28.60 (5.57) | −.166 | .87 |
| EDUCATION, mean (S.D.) | 18.76 (3.26) | 17.87 (3.25) | 19.71 (3.01) | −1.57 | .129 |
| IQ, mean (S.D.) | 119.90 (10.66) | 117.93 (11.76) | 121.87 (9.41) | −1.01 | .32 |
| GROSS INCOME, mean (S.D.) | 5.10 = 50–75K (2.06) | 5.27 = 50–75K (1.58) | 4.93 = 30–50K (2.53) | .435 | .67 |
| FEMALE (%) | 53.3 | 53.3 | 53.3 | | 1 |
| ETHNICITY | | | | | 1 |
| Asian (%) | 20.0 | 20.0 | 20.0 | | |
| Caucasian (%) | 66.67 | 66.67 | 66.67 | | |
| Multiple/other (%) | 13.3 | 13.3 | 13.3 | | |

* Significance values were derived from Fisher's exact and $t$ tests.

### 2.2. Intervention

Details of the CCBP and LCBP intervention have been described elsewhere (Hawthorne et al., 2013; Kienitz et al., 2014). To summarize, both interventions included five weekly 2-h group classes. The CCBP was an interactive studio where participants build their creative confidence and sharpened their individual design thinking skills through hands-on experiences. The program aimed to encourage participants to develop a bias toward action and to promote self-awareness of designer skills. In an open studio setting, participants worked individually on fast-paced immersive tasks. Hands-on activities incorporated the use of everyday office supplies as materials. Participants reflected on their exercises through post-activity tasks and viewing other participants' work. Each training session included a variety of activities that were made known to them as they were assigned. Over the course of the 5-week training each of following eight topics were introduced with associated experiential tasks and activities: (a) see – to reduce perceptual bias; (b) start – to induce bias toward actions using rapid prototyping; (c) build – to enhance manual dexterity by building 3D prototype; (d) feel – to sharpen affective processing for better empathizing; (e) communicate – to enhance listening and communication skills; (f) inspire – to seek active inspiration from everyday incidence; (g) synthesize – to combine disparate constructs in order to create novel ideas; and (h) navigate – to reduce the fear of failure and uncertainty.

The LCBP intervention also consisted of many hands-on exercises to learn basic Chinese vocabulary, character writing, and basic phrases (e.g. How are you?), taught by a bilingual native Mandarin speaker. These exercises were performed in a group setting to simulate the shared environment atmosphere of the CCBP studio. Participants copied and practiced Chinese characters with regular pens and traditional Chinese brush and ink (calligraphy) on tracing books. This aspect of the intervention provided hands on exercise while minimizing creative generation of ideas.

### 2.3. Measures

#### 2.3.1. The Delis–Kaplan Executive Function System (D-KEFS)

We administered three subtests of the D-KEFS to measure executive functioning pre and post-intervention, including Color–Word Interference, Verbal Fluency, and Design Fluency. For all these subtests, scaled scores for speed, accuracy, and errors were calculated according to D-KEFS scoring procedures. D-KEFS Scaled Scores have a mean of 10 and a SD of 3 (Delis, Kaplan, & Kramer, 2001).

The Color–Word Interference Test (CWIT) was used as our primary outcome measure. The CWIT is based on the Stroop (1935) procedure. CWIT consists of four conditions. The first two conditions of the task assess "lower-level" goal-directed attention and processing speed, whereas the last two conditions assess "higher-level" inhibition and cognitive flexibility. In the first condition, color naming, the participant names the color of a series of red, green, and blue squares. In the second condition, word reading, the participant reads the words "red," "green," and "blue" printed in black ink. The color naming and word reading conditions are measures of executive function employed to assess attention (Tremblay, Monchi, Hudon, Macoir, & Monetta, 2012; Vartanian et al., 2007), processing speed (Pukrop & Klosterkotter, 2010; Tremblay et al., 2012; Vartanian et al., 2007), working memory (Pukrop & Klosterkotter, 2010), and visuomotor sequencing (Bondi et al., 2002). In the third condition, which tests for inhibition, participants name the color of the ink of the words "red," "green," and "blue" printed incongruently in red, green, or blue ink. Lastly in the fourth condition, which involves inhibition and switching, the participant is asked to state the color of the ink in which each word is printed (as in the third condition), but to read the word aloud (and not name the ink color) when a word appears inside a box. Half of these words are enclosed within boxes. The inhibition and inhibition/switching conditions are measures of executive function employed to assess task switching (Delis et al., 2001), and inhibition of prepotent responses (Stroop, 1935). For all four conditions, participants are instructed to complete the task as quickly as possible without making mistakes. Performance is measured by completion time on each of the four conditions. In addition, a scaled score was calculated for combining the color naming and word reading conditions. Higher scaled scores correspond to faster overall completion time. Three contrast scores (inhibition vs. color naming, inhibition/switching vs. combined color naming and word reading, and inhibition/switching vs. inhibition) were also obtained to determine whether there is a discrepancy between "lower-level" attention and processing speed (color naming and word reading conditions) compared to "higher-level" inhibition and cognitive flexibility (inhibition and switching conditions). Lower scaled scores correspond to a greater difference between compared completion times.

The Verbal Fluency subtest was used to measure individuals' capacity for fluid generation of verbal ideas. In 1 min, participants were asked to list as many words as they can that start with either the same letter (Verbal Fluency), the same category (Category Fluency), or to alternate between two categories (Category Switching).

The Design Fluency subtest was used to measure individuals' capacity for fluid generation of rules-based visual ideas. This subtests requires generation of as many unique visual designs as possible within a 1-min time limit by connecting dots with our without distractors (Filled Dots and Empty conditions) or by alternating between filled and empty dots (Dot Switching condition). Verbal and Design Fluency were administered as exploratory outcome measures, in addition to the primary outcome measure.

#### 2.3.2. The Wechsler Abbreviated Scale of Intelligence-II

Additionally, the Wechsler Abbreviated Scale of Intelligence-II was used to measure general intelligence pre-intervention (WASI-II, Psychological Corporation, 2011). The WASI-II is designed to be administered individually in approximately 30 min.

**Table 2**
Post hoc analysis of errors on CWIT color-naming, word-reading, and inhibition/switching.

| Variable | Pre or post intervention | CCBP ($N$ = 15) | LCBP ($N$ = 15) | $T$ |
|---|---|---|---|---|
| TOTAL ERRORS COLOR NAMING | Pre | .67 (1.11) | .333 (.488) | 1.063 |
| TOTAL ERRORS WORD READING | Pre | .20 (.41) | .333 (.488) | −.807 |
| TOTAL ERRORS INHIBITION/SWITCHING | Pre | 1.27 (1.91) | .867 (.915) | .732 |
| TOTAL ERRORS COLOR NAMING | Post | .33 (.488) | .867 (2.56) | −.793 |
| TOTAL ERRORS WORD READING | Post | .53 (.83) | .40 (.632) | .493 |
| TOTAL ERRORS INHIBITION/SWITCHING | Post | 1.40 (1.40) | .867 (.743) | 1.30 |

The measure consists of 4 subtests: Vocabulary, Similarities, Block Design, and Matrix reasoning used to obtain Full Scale IQ (FSIQ). The WASI-II has a mean of 100 and a SD of 15.

*2.3.3. Demographic and socio-economic status survey*

We also created a short survey to collect age, sex, ethnicity, and socio-economic status pre-intervention. For ethnicity, we asked participants if they belonged to one of the following categories: African American; Asian; Native American; Pacific Islander; White/Caucasian; Other. For socio-economic status, we asked if their household annual income belonged to one of the following categories: <10 K; 10–20 K; 20–30 K; 30–50 K; 50–75 K; 75–100 K; 100–125 K; 125–150 K; 150–200 K; >200 K.

## *2.4. Statistical analysis*

All analyses were performed using SPSS version 20. We verified that participant data did not exceed 2 SD from the group mean on all pre- and post-intervention measures. Independent Sample *t*-tests were used to determine if there were significant differences between groups on age, IQ, and education pre-intervention. Chi-square tests were used to determine if there were significant differences between groups on sex and ethnicity. ANCOVAs were utilized to determine if the dependent variable (D-KEFS scores post-intervention) differed between groups (CCBP vs. LCBP) with D-KEFS scores pre-intervention as covariates.

# **3. Results**

## *3.1. Sample characteristics*

Thirty individuals completed both pre- and post-intervention assessments ($N$ = 30; 16 F, 14 M). There was no difference between groups on age, years of education, IQ, gross income, sex and ethnicity between the CCBP and LCBP groups (Table 2).

## *3.2. Lower-level executive function*

We examined the hypothesis that inclusion in the CCBP (vs. LCBP) group would be associated with higher standard scores post-intervention on D-KEFS measures assessing lower-level executive functioning. ANCOVAs were performed to examine group differences post-intervention on the D-KEFS CWIT standard scores for the color naming, word reading, and color naming + word reading combined conditions. Pre-intervention scores were entered as covariates in each ANCOVA.

An ANCOVA revealed significant group difference (CCBP vs. LCBP) post-intervention for the lower level executive function measure of color naming + word reading completion time, ($F(1, 30) = 9.925$, $p = .004$, Cohen's $d = .60$). For the CCBP group, completion times were faster at post-intervention compared with pre-intervention as demonstrated by the increase in scaled scores. For the LCBP group, completion times did not change from pre- to post-intervention (Fig. 2).

## *3.3. Higher-level executive function*

We examined the hypothesis that inclusion in the CCBP (vs. LCBP) group would be associated with higher standard scores post-intervention on D-KEFS measures assessing higher-level executive functioning. ANCOVAs were performed to examine group differences post-intervention on the D-KEFS CWIT standard scores for the inhibition and inhibition/switching conditions. There was no significant difference between groups on these two scores measuring higher-level executive function.

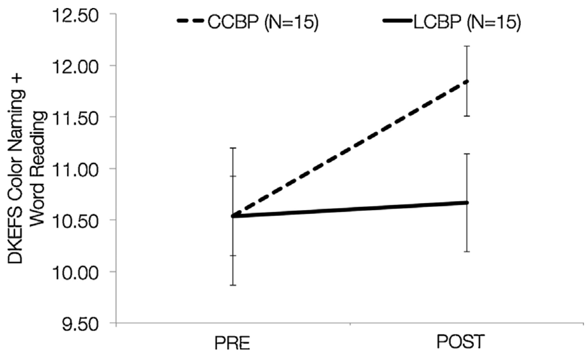


**Fig. 2.** D-KEFS Color–Word Interference: Pre–Post Combined Completion Time of Color Naming + Word Reading Scaled Score (higher score = faster completion time).

### 3.4. Comparison of higher-level vs. lower-level executive function

ANCOVAs were also performed to examine group differences post-intervention on the D-KEFS CWIT standard scores for the contrasts between higher-level and lower-level executive function (inhibition vs. color naming and inhibition/switching vs. combined color naming and word reading). A significant group difference post-intervention for the contrast score comparing higher-level (inhibition/switching) vs. lower-level (combined color naming + word reading) completion time was observed ($F(1, 30) = 9.527$, $p = .005$, Cohen's $d = .70$). For the CCBP group, the contrast between completion times increased from pre- to post-intervention as demonstrated by a decrease in scaled scores (Fig. 3).

### 3.5. Response accuracy

In order to assess whether response completion times on the color naming, word reading, and inhibition/switching conditions affected accuracy, post hoc analyses were conducted to determine whether groups differed in total errors (uncorrected and self-corrected). Student's *T*-tests revealed no significant differences between groups in total errors on each condition (Table 2).

### 3.6. D-KEFS Verbal and Design Fluency

We examined the hypothesis that inclusion in the CCBP (vs. LCBP) group would be associated with higher scaled scores on Verbal and Design Fluency subtests, indicative of enhanced performance post-intervention on D-KEFS measures assessing higher-level executive functioning. No significant group differences were detected for these measures (all $p$-values > .05).

## 4. Discussion

This study examined the effects of a creativity training intervention on executive functioning. The study design consisted of random assignment to a creativity training program and a control group and assessments of creativity and executive functioning pre and post-intervention. As reported in our companion paper (Kienitz et al., 2014), we found that the CCBP intervention enhanced creativity in adults. This suggests that individual creative potential is not static, but rather a fluid construct, and one that can be individually strengthened through targeted training.

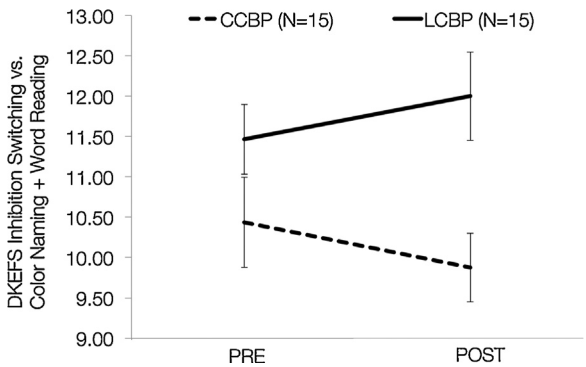


**Fig. 3.** D-KEFS Color–Word Interference: Pre–Post Primary Contrast Measure Scaled Score (lower score = greater difference between completion times).

Our results show that the creativity training used here was associated with increased "lower-level" executive functioning, specifically goal-directed attention and information processing during a task with little cognitive interference. These results support the first part of our primary hypothesis. Specifically, improvement in lower lower-level executive functioning was observed for the color naming and word reading conditions of the D-KEFS Color Word Interference Task. These results also support Martindale's theory that attention in creative people is a variable state, dependent upon task demands (Martindale, 1999). Martindale suggests that creative people show enhanced performance on attention tasks with little cognitive interference, such as the color naming and word reading conditions of the CWIT, while they show decreased performance on tasks where many distractors are present, a condition not replicated in our study.

Our results are not likely due to experimental error because the CWIT congruent conditions have high test–retest reliability (Wostmann et al., 2013). Further, the improvements in completion times were not due to decrements in accuracy. The participants processed unambiguous information faster and remained accurate (Table 2). This provides further support that the creativity intervention affected a substantial enhancement of goal-directed attention and information processing. Many of the hands-on exercises in the CCBP required participants to complete creative productions in a set amount of time. It is not surprising that improvements in completion times were found for the color-naming and word-reading conditions, as opposed to other D-KEFS conditions, because color-naming and word-reading are highly automatic and pre-potent processes in adults. Thus, the CCBP seems to increase productivity of automatic processes, which is in line with design teaching theory that creativity is, in part, a function of productivity, with greater productivity yielding superior creative solutions (Goldenberg, Mazursky, & Solomon, 1999; Toubia, 2006).

This increase in productivity of automatic processes may also speak to the notion of creative metacognition, which Kaufman and Beghetto (2013) define as "a combination of creative self-knowledge (knowing one's own creative strengths and limitations, both within a domain as well as a general trait) and contextual knowledge (knowing when, where, how, and why to be creative)." This description of creative metacognition dovetails with Martindale's theory of differential task-demand attention in creative individuals (Martindale, 1999). In addition, the enhancement of processing speed on tasks with little cognitive interference may point to CCBP-specific improvement in the ability to think creatively during ambiguous situations, as well increase automatic processing during unambiguous situations.

We failed to find differences from pre to post-intervention in higher-level executive functioning, namely inhibition and cognitive set-shifting, which does not support the second part of our hypothesis. It is possible that higher-level executive function is less amenable to change, especially in a group of people with already high baseline executive functioning abilities like this study's participants. In this case, a plateau could have reached where better higher-level executive function as baseline limits the possibility of intervention-based enhancement. Alternatively, it may be that the duration of the creativity intervention was not long enough to effect change in higher order executive functioning, or that a different kind of creativity intervention is needed to effect change in these higher order functions. Future work in this area is required to explain the lack of change in higher-level executive functioning associated with creativity training.

The DKEFS provides contrast scores that determine whether there is a discrepancy between "lower-level" compared to "higher-level" executive function. We observed a between-group difference on the contrast score comparing higher-level (inhibition/switching) vs. lower-level (combined color naming + word reading) completion time, with lower contrast scores post-intervention for the CCBP group compared to the LCBP group. Of note, the decrease in contrast score does not indicate a decrease in performance. On the contrary, it is attributable to increased (faster) performance on the combine color naming and word reading conditions while the performance on the inhibition/switching condition did not change.

Our results provide support to the growing body of evidence suggesting that creativity is related to executive functioning (Benedek, Koenen, & Neubauer, 2012; Dorfman et al., 2008; Gilhooly et al., 2007; Golden, 1975; Groborz & Necka, 2003; Kwiatkowski et al., 1999; Mednick, 1962; Nusbaum & Silvia, 2011; Vartanian et al., 2007; Zabelina & Beeman, 2013; Zabelina & Robinson, 2010). Further, the results of this study suggest that the type of creativity training utilized in this study specifically affects goal-directed attention and processing speed. This supports previous findings showing that creative potential has been associated with differential focusing of attention and with a narrowing of the focus of attention associated with faster processing (Dorfman et al., 2008; Kwiatkowski et al., 1999; Vartanian et al., 2007; Zabelina & Beeman, 2013). The increase in scaled scores in the CCBP group represents a 10% decrease in total completion time from pre- to post-intervention assessment on the CWIT across the color naming and word reading conditions. In addition to faster processing speed on overall task completion as shown here, it would be valuable to measure the reaction time to stimuli within tasks in future studies. Studies employing behavioral interventions have documented increases in sustained attention and cognitive processing speed as observed through faster performance on reaction time tasks (Hirano et al., 2013; Tucha, Mecklinger, Maier, Hammerl, & Lange, 2004).

Although replication of effects from creativity interventions on a larger number of participants is needed to validate the results found in this study, the medium to large effect sizes (Cohen's $d$ .60 and .70) suggest that the findings are likely to generalize to a larger group. Another limitation to be observed is that only one specific low-interference task and one high-interference task (CWIT conditions) were used. While the CWIT tasks are valid measures of attention and processing speed (Bondi et al., 2002; Dorfman et al., 2008; Pukrop & Klosterkotter, 2010; Tremblay et al., 2012), and prepotent response inhibition (Comalli, Wapner, & Werner, 1962; Delis et al., 2001; Friedman & Miyake, 2004), it is unclear whether our findings would generalize to other components of cognitive inhibition, e.g., suppression of interfering stimuli or presence of distractors (Friedman & Miyake, 2004). Future studies, therefore, should address the question whether different inhibition-related functions differentially contribute to creative thought. Although every effort was taken to match the two interventions (e.g.

motivation of the instructor, timing, etc.), the participants' knowledge that they were enrolling in a creativity class represents an additional limitation of this study. This knowledge may have contributed to a motivational bias that led to enhanced performance. Finally, this study did not include a measure of convergent thinking, which has also been implicated in the production of creative outcomes (Bowden & Jung-Beeman, 2003; Kounios & Beeman, 2014), and while our lower-level EF task and results may serve as a proxy for convergent thinking, future studies should include discreet measures of convergent thinking to better evaluate associated gains.

Altogether, our study supports the emerging notion that creativity draws on executive processes, providing evidence that enhanced creativity is associated with increased focusing of attention and faster processing speed on tasks with little cognitive interference. Our study is the first of its kind to demonstrate that creativity intervention can increase an individual's creative production and enhances specific components of neurocognitive function putatively associated with creativity.

## Conflicts of interest

None declared.

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