

# CREATIVITY: EDUCATION AND REHABILITATION

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# CREATIVITY: EDUCATION AND REHABILITATION

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Creativity has the potential to improve quality of life. It can also be conceived as a tool in educational and rehabilitation settings. Therefore, it is the aim of this Research Topic to further show how creativity can be used and encourage the application of creativity in pedagogical and clinical contexts.

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# Editorial: Creativity: Education and Rehabilitation

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**Keywords:** creativity, divergent thinking, children, aging, pedagogy, representation

## Editorial on the Research Topic

### Creativity: Education and Rehabilitation

Creativity is a multifaceted phenomenon which entails generation of new ideas to solve problems and produce innovation. It is also conceived as a means to improve the quality of life, and promote general health in both normal and clinical populations. This has progressively lead the scientific community to investigate creativity, and its inherent components (e.g., divergent thinking), in terms of cognitive processes (Palmiero et al., 2016a,b; Zedelius and Schooler, 2016) and age-related changes (Palmiero, 2015; Palmiero et al., 2017) to support educational success (Plucker et al., 2004), active aging (Palmiero et al., 2016c), and rehabilitation (Palmiero et al., 2012).

Although creativity represents a window for expressing the self and enhancing well-being, several issues remain to be investigated to clarify the extent to which idea generation and/or art expression can be used for educational and rehabilitation purposes. This Frontiers in Cognition Research Topic was explicitly devoted to shed light to some extent on these issues. Ten novel publications were collected: 7 Original Research Articles, 1 Brief Research Report Article, and 2 Reviews.

Regarding the role of creativity in educational settings, an enriching program for gifted children (6 to 10-years old) in the areas of language and science showed positive effects only on intelligence operating in well-defined problem space (Welter et al.). In this vein, in children and adolescents, drama pedagogy training was related to divergent thinking and problem-solving if based on storytelling, pretend-play and playfulness, and to risk or perspective taking if based on improvisation and role-play (Celume et al.). Interestingly, multiple sessions of improvisational theater improved both teenagers' flexibility and originality of verbal divergent thinking (Hainselin et al.). These studies showed the potential of creativity in educational settings in a wide range of domains, suggesting the need to operate in different types of problem space. Other studies highlighted the key role of mediating factors. Children (6 to 10-years old) practicing dances showed higher ability in representing the topological map of the body, which mediated their divergent thinking ability in motor domain (Palmiero et al.). Adolescents' (16 to 19-years old) cognitive self-regulation mediated the relationships between mind wondering and verbal divergent thinking (Preiss et al.). In people aged 12–88 years, gender, age, and composite intelligence quotient predicted creative achievement, whereas interpersonal emotional competence predicted creative style (Nori et al.).

Regarding the role of creativity in rehabilitation settings, spatial distortions in patients' drawings after right brain damage (unilateral spatial neglect, hyperschematia, constructional apraxia) was

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related to the space representation in art (Rode et al.). This means that the understanding of the pathological mechanisms underlying these disorders provides not only an opportunity to clarify visual art, but also gives the possibility to use visual artistic creativity to improve the spatial distortions after brain damages. Moreover, verbal divergent thinking, which positively correlated to the integration of the default mode network and cerebellum, was suggested for treating depression (Feng et al.), which is characterized by a reduced functional connectivity between the cerebellum and the default mode network (Liu et al., 2012). Yet, creativity was associated with the rehabilitation of schizophrenia: high schizotypal individuals exhibited higher over-inclusive thinking and cognitive inhibition, which partially mediated the relationship between schizotypy and creativity (Wang et al.). Finally, the relationships between different proxies of cognitive reserve and verbal divergent thinking were also showed, in light of the creative jobs rather than of the job complexity (Colombo et al.), confirming that creativity, and its components, might be aimed at fostering active aging.

In summary, from the knowledge we acquired by the studies collected in this Research Topic, it is possible to underline that creativity represents a flexible tool for enhancing cognition and

promoting well-being during the lifespan. Much work is still necessary, of course, but there is no doubt that the application of creativity in education and rehabilitation settings represents a new research frontier. Moving forward, the challenge will be to understand the interrelations between creativity, cognitive, extra-cognitive, and personality factors in order to foster efficient educational and rehabilitation programs. Importantly, given that creativity involves different sub-components, such as divergent and convergent thinking, it would be interesting to investigate these components more systematically in future studies. Then, it might be useful to also consider the efficacy of creativity in educational and rehabilitation settings in relation to different domains of knowledge (e.g., visual, auditory, motor, etc.).

In conclusion, the variety of approaches and insights gained certainly offer a new and encouraging window to continue to work in this fascinating field.

## AUTHOR CONTRIBUTIONS

MP: planned the topic and edited the most of papers included in the topic. LaP: planned the topic. RN, LiP, CS, and CG: edited some papers included in the topic.

## REFERENCES

- Liu, L., Zeng, L. L., Li, Y., Ma, Q., Li, B., Shen, H., et al. (2012). Altered cerebellar functional connectivity with intrinsic connectivity networks in adults with major depressive disorder. *PLoS ONE* 7:e39516. doi: 10.1371/journal.pone.0039516
- Palmiero, M. (2015). The effects of age on divergent thinking and creative objects production: a cross-sectional study. *High Abil. Stud.* 26, 93–104. doi: 10.1080/13598139.2015.1029117
- Palmiero, M., Di Giacomo, D., and Passafiume, D. (2016c). Can creativity predict cognitive reserve? *J. Creat. Behav.* 50, 7–23. doi: 10.1002/jocb.62
- Palmiero, M., Nori, R., and Piccardi, L. (2016a). Visualizer cognitive style enhances visual creativity. *Neurosci. Lett.* 615, 98–101. doi: 10.1016/j.neulet.2016.01.032
- Palmiero, M., Nori, R., and Piccardi, L. (2017). Verbal and visual divergent thinking in aging. *Exp. Brain Res.* 235, 1021–1029. doi: 10.1007/s00221-016-4643-3
- Palmiero, M., Piccardi, L., Nori, R., Palermo, L., Salvi, C., and Guariglia, C. (2016b). Editorial: creativity and mental imagery. *Front. Psychol.* 7:1280. doi: 10.3389/fpsyg.2016.01280
- Palmiero, M., Di Giacomo, D., and Passafiume, D. (2012). Creativity and dementia: a review. *Cogn. Process.* 13, 193–209. doi: 10.1007/s10339-012-0439-y
- Plucker, J. A., Beghetto, R. A., and Dow, G. T. (2004). Why isn't creativity more important to educational psychologists? Potentials, pitfalls, and future directions in creativity research. *Educ. Psychol.* 39, 83–96. doi: 10.1207/s15326985ep3902\_1
- Zedelius, C., and Schooler, J. (2016). The richness of inner experience: relating styles of daydreaming to creative processes. *Front. Psychol.* 6:2063. doi: 10.3389/fpsyg.2015.02063

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# The Dancers' Visuospatial Body Map Explains Their Enhanced Divergence in the Production of Motor Forms: Evidence in the Early Development

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Dance represents an opportunity to promote not only motor skills but also other cognitive functions and general well-being. In this study, 58 children aged 6–10 years were enrolled in order to test the issue if dance improves divergent thinking in motor and visual domains (domain-general and domain-specificity hypotheses), and whether the topological map of the body mediates their performance at the motor task (mediation hypothesis). Therefore, 33 children practicing dance were compared with a control group (25 children). Children were administered the visual divergent thinking task of the Torrance Test of Creative Thinking, consisting in making drawings starting from given shapes, and the motor-form divergent thinking task, opportunely developed consisting in producing acted motor forms in the extrapersonal space. Both tasks were presented for 10 min and were scored in terms of fluency, flexibility, and originality. The ability to form the topological map of the body was measured by the frontal body-evocation test. Results revealed that children practicing dance outperformed the control group only in terms of the ability to perform motor forms. In addition, dancers showed a better topological map of the body, and, most importantly, besides the direct effect of group on the ability to produce acted motor forms, a significant indirect effect of the group, mediated by performances on frontal body-evocation task, was found. These results have important implications for cognition, showing that dance can improve the topological map of the body that in turn enhances creativity in motor domain since the early developmental age.

**Keywords:** dance, divergent thinking, creativity, visual, motor, verbal, education, expertise

## INTRODUCTION

Positive effects of physical activities on different cognitive aspects have been widely documented over the years. For example, agonistic athletes are faster at mentally rotating objects (Ozel et al., 2002), whereas individuals who performed orienteering and geocaching improved their visuospatial skills (Barnikel et al., 2014; Ellbrunner et al., 2014; Schmidt et al., 2016). Physical



activity produces benefits also on child development (e.g., Iivonen et al., 2013; Zeng et al., 2017), increasing the possibilities of learning at school (Singh et al., 2012; Hillman and Biggan, 2017). In particular, dance promotes motor development and communicative skills in children (Pavlidou et al., 2018).

A growing number of studies has also demonstrated that dance improves kinetic consciousness and by consequence motor creativity and self-expression (Kalliopuska, 1989; Castañer et al., 2012; see for a review, Pavlik and Nordin-Bates, 2016), regardless of age. Indeed, the use of motor imagery to create new movements enhances creativity in dancers of all ages (Purcell, 1990; Sacha and Russ, 2006; Couillandre et al., 2008). However, the extent to which dance can improve creativity and divergent thinking in other domains has to be still clarified. Specifically, divergent thinking measures the creative potential, reflecting the ability to find many different solutions to the same open-ended problem (Guilford, 1950, 1967; Guilford et al., 1978). For instance, the Alternate Uses Test (Guilford et al., 1978) requires one to think of different uses for a common object (e.g., a brick can be used as a weapon) and is scored in terms of fluency (responses provided in a given time), flexibility (categorical shifts in responses), originality (the extent to which responses are infrequent), and elaboration (details provided along with the responses). Basing on Guilford's seminal work, different divergent thinking tests were developed, in visual and verbal forms (e.g., Torrance, 1987), as well as in motor forms (e.g., Wyrick, 1968; Castañer et al., 2009; Scibinetti et al., 2011; Moraru et al., 2016), which are based on the production of as many actions as possible (e.g., stepping, skipping).

Well, on the one hand, modern/contemporary dancers, who basically freely improvise on stage, were found to exhibit high levels of divergent thinking in verbal and figural domains, followed by jazz/musical and then by ballet dancers (Fink and Woschnjak, 2011). In addition, professional ballet/modern dancers were found to produce higher ideational fluency than novices in verbal divergent thinking as measured by the alternative uses task (Fink et al., 2009). These results suggest that differences in divergent thinking depend on the type of dance practiced. Dance improvisation seems to enhance the creative potential more than classical dance. Even in non-professional dancers, short periods of dance improvisation (5 min) increased emotional well-being, which in turn produced higher fluency of verbal divergent thinking (Campion and Letiva, 2014). On the other hand, investigating the relation between creative ability in choreographic dancers and selected attributes of verbal and visual divergent thinking, Brennan (1982) found that measures of verbal and visual divergent thinking were not related to the measures of creative dance, suggesting that originality and flexibility of movements represent distinct divergent production abilities. Stinson (1993) also showed that students in Chinese dance education produced significantly lower scores in fluency, flexibility, and originality of visual and verbal divergent thinking than a non-dancing control group.

Although these results are contradictory, dance—as a form of art—undoubtedly involves creativity and divergent thinking,

specifically in the motor domain (Alter, 1999). In this vein, several studies suggested that creativity (e.g., Plucker and Beghetto, 2004; Kaufman and Baer, 2005; Silva et al., 2009; Palmiero et al., 2015; Palmiero et al., 2016b) and divergent thinking (Palmiero et al., 2010; Boccia et al., 2015) are domain-specific. Palmiero et al. (2010) found that divergent thinking in verbal domain is mostly domain-specific, but can also be affected by general processes that underpin visual skills, such as vividness of visual mental imagery, whereas divergent thinking in visual domain is exclusively domain- and task-specific. However, elsewhere, the view that divergent thinking presumably fosters creativity across domains is supported (Silvia, 2008a,b).

On the other hand, several studies demonstrate that practicing a sport produces changes not only in cognitive and motor skills, but also on body awareness. For example, Fonseca et al. (2014) demonstrated that when 15 ballroom dancing beginners received a 1-week training per 3 months, they subsequently produced an increase of body awareness with respect to 15 controls matched for age who received no training in dance but only theoretical lessons about body perception. These results are in line with Damasio (2010), who suggests that movements allow to build up new cortical maps, increasing the repertoire of new possible motor responses. More specifically, the topological map of the body is a dynamic mental representation relevant for action and integration with the environment (Paillard, 1980) coming from tactile, proprioceptive, and kinesthetic information, as well as from environmental stimuli (Schwoebel and Coslett, 2005; Cardinali et al., 2009; Vignemont, 2010). Thus, dancing improves body awareness (e.g., Fonseca et al., 2012, 2014) on the basis of the movements of the body parts, activating the proprioceptive receptors and postural sensitivity, and informing the brain about the position of the trunk and segments (Thurm et al., 2011). Creative dance movement seems to increase also satisfaction with body appearance, fitness, and body parts, especially in experienced groups of dancers (Lewis and Scannell, 1995).

With this in mind, in the present study, we aimed at clarifying the extent to which dance can improve motor and visual divergent thinking in child development, and if the topological map of the body mediates motor divergent thinking in dancer children. We enrolled children 6–10 years old because as stated in developmental literature, childhood involves significant physical and cognitive changes including: body changes (i.e., weight; height; muscular tone and mass), motor activity (motor coordination and goal finalized actions) and logical processing of reasoning (Piaget, 1952). According to Piagetian developmental theory, children start to reason in terms of theories and abstractions, as well as concrete realities. They are capable of creating logical structures that explain their physical experiences. Not least at this developmental stage corresponds the beginning of the formal education, and different studies demonstrated that at this age, motor activity, including dance, has positive effects on learning (Singh et al., 2012; Hillman and Biggan, 2017).

According to Whitehead (2010), “physical literacy” is an opportunity to generate significant benefits for both specific- and cross-domain learning. Here, we compared children with and without dance experience in visual and motor divergent

thinking. Visual divergent thinking was measured by the completion of drawing task included in the battery of Torrance Test of Creative Thinking (Torrance, 1987). With respect to motor divergence, a motor task aimed at measuring the ability to produce different motor forms (e.g., the body posture that a football player takes while kicking the ball), rather than different actions per se (e.g., the action to kick the ball), was opportunely developed. We also assessed whether motor divergent thinking skills were mediated by body representation, which was tested by asking children to form the topological map of the body task (TMB; Daurat-Hmeljiak et al., 1978; Cannoni and Tega, 2009; Di Vita et al., 2019). The novelty of this study is two-fold: first, it explores the extent to which dance promotes motor and visual divergent thinking in children; second, it assesses if the topological map of the body mediates motor divergent thinking in dancer children.

Basing on previous findings, hypotheses were formulated as follows:

1. the dance background improves both visual (e.g., Fink et al., 2009; Fink and Woschnjak, 2011) and motor divergent thinking (domain-general hypothesis);
2. the dance background has a specific effect only on motor divergent thinking (e.g., Brennan, 1982; Stinson, 1993) (domain-specific hypothesis);
3. the ability to form the topological map of the body is better in dancers than non-dancers (e.g., Fonseca et al., 2012, 2014) on the basis of a better postural sensitivity and body awareness;
4. the improvement in motor divergent thinking is mediated by the improvement in topological map of the body in dancers (mediation hypothesis).

## MATERIALS AND METHODS

### Participants

A total of 58 children participated in this study (age range: 6–10 years). They were subdivided into two groups as follows: the experimental group was composed by 33 ballet dancers (22 girls and 11 boys; mean age = 8.4 S.D.  $\pm$  1.27; dance expertise in years = 2.94 S.D.  $\pm$  1.50) of the different gyms belonging to the amateur sportive association “The Starlight Company” located in Rome; the control group was composed by 25 non-dancers (11 girls and 14 boys; mean age = 7.92 S.D.  $\pm$  1.50) of the same gyms. The two groups did not differ in age ( $F_{(1,56)} = 1.69$ ,  $p = 0.19$ ). The non-dancers practiced other types of physical activities (e.g., volleyball and football). All children were Italian native speakers and attended the primary school. Children with learning difficulties and other neurodevelopmental diseases were not included in the sample. As reported by parents during an informal interview, children had no primary visual or hearing impairments, no neurological conditions, and no emotional or behavioral problems. The study was approved by the Ethics Committee of University of L'Aquila in accordance with the Declaration of Helsinki. A signed informed consent was obtained from parents and an assent from each child.

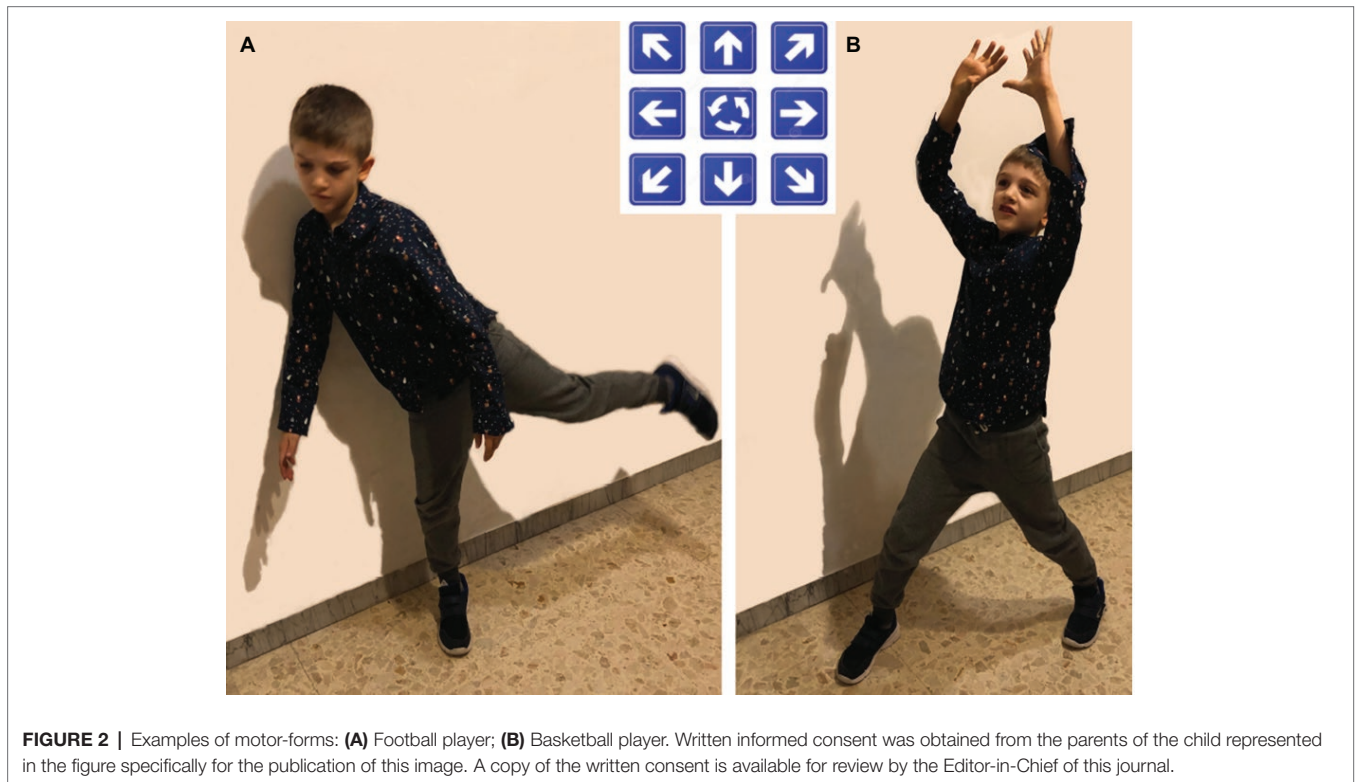
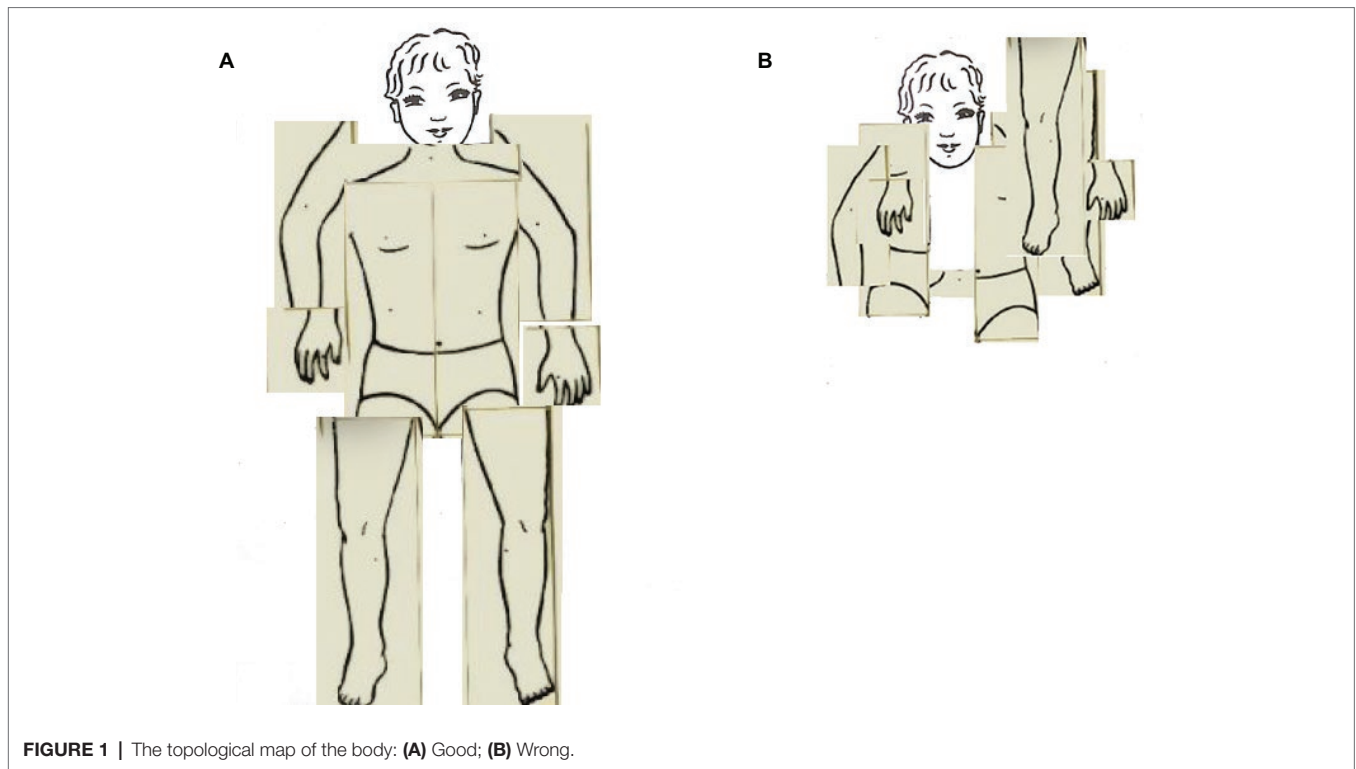
## MATERIALS AND PROCEDURE

### The Topological Map of the Body Task (Daurat-Hmeljiak et al., 1978; Lis and Tallandini, 1981, for the First Italian Standardization and Cannoni and Tega, 2009, for an Updating of the Italian Normative Data)

The topological map of the body (TMB) was assessed using the Frontal body-evocation subtest (FBE) of the Body Representation Test (Daurat-Hmeljiak et al., 1978; Cannoni and Tega, 2009). This task is still largely used in its original and adapted versions both in clinical and experimental settings over the life span to study alterations in the mental representation of the relations between body parts (e.g., Guariglia et al., 2002; Marangolo et al., 2003; Di Russo et al., 2006; Canzano et al., 2011; Cimmino et al., 2013; Fuentes et al., 2013; Palermo et al., 2014; Bassolino et al., 2015; Di Vita et al., 2015, 2017; Spitoni et al., 2015; Zantedeschi and Pazzaglia, 2016; ; Perez-Marcos et al., 2018). Task materials included a small plastic board on which the position of the head was depicted as a reference part, and nine tiles, each representing a body part. Children were presented with one tile at a time and their task was to name the body part depicted on the tile; then, they were instructed to place each tile on a board, on which was depicted only a child's face. Before showing a new tile, the position of the previous tile was recorded by overlapping a transparent grid and the tile was removed. The number of correct answers was recorded (Max = 9) as well as the response time expressed in seconds (see **Figure 1**).

### The Visual Divergent Thinking Task (From Torrance Test of Creative Thinking—Form A (Torrance, 1987); Italian version, Sprini and Tomasello, 1989)

This task asked children to make drawings starting from given shapes within 10 min. Basically, a paper sheet with 10 incomplete shapes was presented; children were told to complete the shapes adding details and providing titles along with each drawing. Children could also use colored pencils to make their drawings. This task is also largely used in literature (e.g., Ayob et al., 2012; Palmiero et al., 2016a, 2017; Humble et al., 2018). It allows to assess three basic attributes of visual divergent thinking. First of all, fluency, that is the number of appropriate ideas/drawings provided within a time limit. Secondly, flexibility, that is the number of categories encompassing the ideas underlying the drawings. As reported in the technical manual, the list of categories for each starting shape covered about 99% of the responses provided by the reference sample, formed by 500 people; when the category was not present, the scoring procedure allowed to opportunely generate a new category. The sum of the categories across responses was used as the individual flexibility score. Finally, originality, that is the number of statistically infrequent ideas provided by a reference sample reported in the technical manual: responses provided by 5% or more of 500 people were scored 0 for originality; responses provided by 2–4.99% of 500 people 1 point; responses provided



by <2% of 500 people 2 points; responses not listed in the technical manual were always given 2 points. The sum of the points across responses was used as the individual originality score.

### The Motor-Form Divergent Thinking Task

This task was opportunely developed for the present study following the logic underlying the visual divergent thinking

task. Participants were asked, without any cues, to perform a free motor action moving from a starting point (from the center of the room) and performing 10 steps in a specific direction (i.e., forward, backward, left, right, diagonally forward left, diagonally forward right, diagonally backward left, diagonally backward right, turn clockwise, and turn counter-clockwise) before executing the invented movement (see **Figure 2**). Participants had to execute more motor actions as possible within 10 min. At the end of the performed action, children were asked to verbally describe the activity performed with a verb or a substantive. The task performance was not videotaped. One experimenter (observer) took notes of the motor forms performed and the description of the action provided by the child. Motor forms that were not recognizable were discarded at first glance. Afterward, the observer and another experimenter evaluated three basic attributes of motor-form divergent thinking, namely fluency, flexibility, and originality, in order to reach an agreement about them. Since this task was conceived on the basis of the visual divergent thinking task, the scoring procedure was the same. For fluency, the experimenters evaluated the number of the movements produced within the 10-min time limit (thus, the fluency score could be higher than 10). For flexibility, the experimenters generated the categories in which the movement forms fell. Categories were opportunely generated according to the movement forms provided. For example, if the child produced a movement form of a floor cleaner, the category “house work” was generated. In this vein, if a movement form of a football player was produced, the category “athletes” was generated. Thus, if the child produced movement forms still related to sport players, the category “athletes” was used to encompass the forms. For originality, the number of statistically infrequent ideas provided by participants of the present study (58 children) was computed as for the visual divergent thinking task: responses provided by 5% or more of 58 children were scored 0; responses provided by 2–4.99% of 58 children 1 point; responses provided by <2% of 58 children 2 points. The sum of the points across responses was used as the individual originality score.

### Administration of the Tasks

The topological map of the body task, the visual divergent thinking task, and the motor-form divergent thinking task were administered in random order across children. The entire experiment lasted approximately 30 min.

### RESULTS

Means and standard deviations of all variables of interest divided per group are reported in **Table 1**.

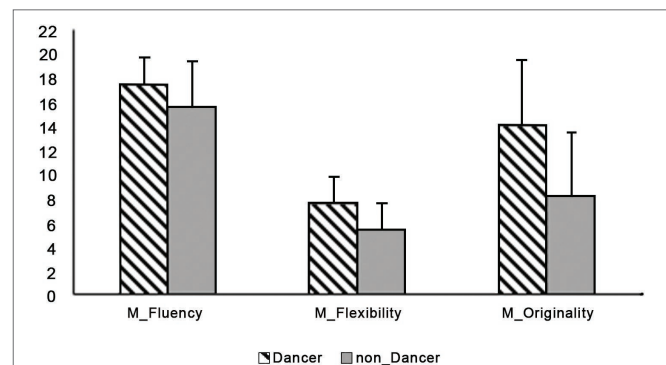
Following the procedure used by Runco et al. (2010), we computed the z-scores of fluency, flexibility, and originality; then, they were summed for obtaining a composite creative index both for visual and motor-form of creative thinking.

In order to exclude effects on visual and motor creativity due to gender, we firstly performed two separate one-way

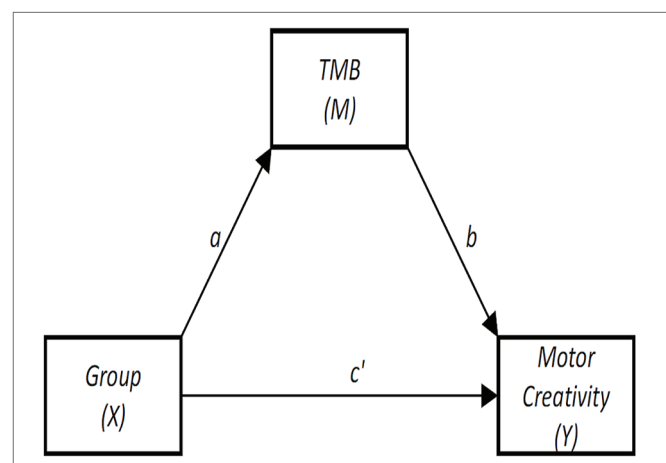
**TABLE 1** | Descriptive statistics.

	No-dance	Dance
Visual fluency	10 (0)	10 (0)
z-Visual fluency	0 (0)	0 (0)
Visual flexibility	7.56 (1.47)	7.91 (1.40)
z-Visual flexibility	-0.14 (1.03)	0.11 (0.98)
Visual originality	10.36 (2.53)	11.09 (2.24)
z-Visual originality	-0.17 (1.06)	0.13 (0.94)
<b>Visual creative index</b>	<b>-0.31 (1.10)</b>	<b>0.24 (1.45)</b>
Motor fluency	15.56 (3.84)	17.42 (2.15)
z-Motor fluency	-0.34 (1.23)	0.26 (0.69)
Motor flexibility	5.48 (2.14)	7.58 (2.25)
z-Motor flexibility	-0.49 (0.88)	0.37 (0.93)
Motor originality	8.16 (5.27)	14.09 (5.38)
z-Motor originality	-0.56 (0.87)	0.42 (0.89)
<b>Motor creative index</b>	<b>-1.39 (2.39)</b>	<b>1.05 (1.84)</b>

Means and standard deviations (s.d.) of raw and z-scores in visual and motor creativity taking into consideration fluency, flexibility, originality, and the complete creative index for both types of creativity. The indices are expressed only in z-scores.



**FIGURE 3** | Means and standard deviations of dancers and no dancers in the three motor components of the motor-form divergent thinking task.



**FIGURE 4** | Template of the mediation analysis. Notes: TMB = topological map of the body.

**TABLE 2** | Mediation analysis.

Variable	M (TMB)				Y (Motor creativity)			
	Path	beta	t	p	Path	beta	t	p
X (Group)	a	1.3394	2.9175	0.0051	c'	1.8767	3.3249	0.0016
M (TMB)		—	—	—	b	0.4224	2.7595	0.0078
		$R^2 = 0.1319, F_{1,56} = 8.5121, p = 0.0051$				$R^2 = 0.3467, F_{2,55} = 14.5935, p < 0.0001$		

Mediation analysis: effects for mediator (M) and independent variable (X) on motor creativity (Y). The indirect effect of X on Y is significant ( $0.5658$ ;  $LLCI = 0.0820$ ,  $ULCI = 1.1989$ ). The direct effect of X on Y (c) is also significant ( $R^2 = 0.2562$ ,  $F_{1,56} = 19.2929$ ,  $p = 0.0001$ ;  $\beta = 2.4424$   $t = 4.3924$ ,  $p = 0.0001$ ). Notes: TMB = topological map of the body.

analyses of variance (ANOVA) with gender (girls vs. boys) as independent variable and composite creative indices (visual and motor) as dependent variables. No differences between groups were detected in visual composite creative index ( $F_{1,56} = 1.74$ ;  $p = 0.19$ ; partial eta-square = 0.03; observed power = 0.25) and in motor-form composite creative index ( $F_{1,56} = 1.79$ ;  $p = 0.19$ ; partial eta-square = 0.03; observed power = 0.26).

Thus, since gender produced no effect on the variables of interest, subsequent analyses were carried out focusing only on differences between dancers and non-dancers.

We performed two separate one-way analyses of variance (ANOVA) with group (dancers vs. non-dancers) as independent variable and composite creative indices (visual and motor) as dependent variables. No differences between groups were detected in visual composite creative index ( $F_{1,56} = 2.51$ ;  $p = 0.12$ ; partial eta-square = 0.043; observed power = 0.34); on the contrary, the two groups differed in motor-form composite creative index ( $F_{1,56} = 19.29$ ;  $p = 0.000$ ; partial eta-square = 0.26; observed power = 0.99): the dance group outperformed the control group (see **Figure 3**).

Thus, we performed a separate ANOVA for each score of the motor-form composite creative index (fluency, flexibility, and originality), with group (dancers vs. non-dancers) as the between factor. Results showed that dancers had a significantly better performance in fluency ( $F_{1,56} = 5.51$ ;  $p = 0.022$ ; partial eta-square = 0.09; observed power = 0.64); flexibility ( $F_{1,56} = 12.85$ ;  $p = 0.001$ ; partial eta-square = 0.19; observed power = 0.94); and originality ( $F_{1,56} = 17.58$ ;  $p = 0.000$ ; partial eta-square = 0.24; observed power = 0.99).

We also analyzed time and accuracy in the topological map of the body task as dependent variables comparing the performance of the two groups (dancers vs. non-dancers) as independent variable. Two separate one-way ANOVAs showed that dancers were more accurate ( $F_{1,56} = 8.51$ ;  $p = 0.005$ ; partial eta-square = 0.13; observed power = 0.82) and faster ( $F_{1,56} = 13.86$ ;  $p = 0.000$ ; partial eta-square = 0.20; observed power = 0.96) than non-dancers in localizing the body parts.

Thus, we directly tested whether the group effect we detected on motor-form of creative thinking was mediated by a more accurate topological map of the body in dancers. Thus, we performed a mediation analysis by using PROCESS (Hayes, 2017) with group (dancers vs. non-dancers) as independent variable (X), motor-form composite creative index as independent variable (Y), and the number of correct answers on TMB

task as mediator (M). **Figure 4** summarizes this model. We found that Y was significantly predicted both by X (path c'; **Figure 4**) and M (path b; **Figure 4**). Also, both direct (path c') and indirect effects of X on Y were significant. Statistics are fully reported in **Table 2**.

## DISCUSSION

Dance has always been considered a means for creativity and self-expression, allowing the expression of kinetic consciousness (Kalliopuska, 1989; Pavlik and Nordin-Bates, 2016) and enhancing positive self-esteem (Alter, 1984). According to Castañer et al. (2016), kinematic parameters expressed by modern dancers also positively influence the observers' aesthetic appraisal. In the present study, we were interested in investigating two different aspects. The first one was related to the extent to which dance can promote not only motor but also visual divergent thinking (or creative index). That is, the issue of domain-specificity of divergent thinking was faced using a dance group of children. Contradictory results provided so far by previous studies led us to formulate two hypotheses: first, dance promotes both visual and motor divergent thinking; second, dance promotes only motor divergent thinking. The second aspect investigated was related to the mediation role of the topological map of the body on motor-form divergent thinking. In line with the evidence that the topological map of the body is progressively elaborated on the basis of sensory afferents that, from the beginning of life, maintain a link with motricity (Case-Smith et al., 2001), we hypothesized that the topological map of the body is generally better in non-dancer children. Since the topological map of the body supplies visuospatial information about the online representations of the body parts (Di Vita et al., 2016; Palermo et al., 2018), we hypothesized that the topological map of the body is crucial in enhancing the motor-form divergent thinking.

Results showed that children engaged in a ballet dance program did not differ from the control group in visual composite creative index, but they did in motor-form composite creative index. This finding is consistent with the domain-specific hypothesis of creativity and the evidence that expertise influences cognition selectively. For example, highly skilled poker players have a larger working memory span (Meinz et al., 2012); military pilots are faster at mentally rotating

objects (Verde et al., 2013) as well as better in navigational skills (Verde et al., 2016), or may be different in moral dilemmas and decision-making (Boccia et al., 2017); video game players outperform novices on tests of visuospatial attention (Green and Bavelier, 2003). More specifically, for motor domain, exergames—namely, videogames based on body interaction because they foster physical exercise while playing (e.g., the Wii)—were found to elicit motor activities, such as motor endurance (e.g., climbing the stairs), stretch (e.g., in jumps), coordination (e.g., controlling the body throughout the activity), and balance (e.g., keeping the body in stability and in control while moving) (Castañer et al., 2016); yet, high-level athletes were found to report higher levels of vividness of motor imagery (Zhang et al., 2018). With respect to creativity, although expertise and creativity are different constructs, in general, creativity often requires some level of expertise, especially in some domains (Baer, 2015). Consistent with this notion, it is possible that being expert in a specific domain predicts creativity only in that domain but not in others, unrelated domains; in addition, it is also possible that people are experts and creative in many different domains, as well as that one cannot simply transfer expertise and creativity across domains (for a review see Baer, 2015). However, regardless of the level of expertise, given that in adults dance was found to increase fluency (Gondola, 1987) and flexibility (Steinberg et al., 1997) of divergent thinking, it is also possible that in the present study, dance improved only motor divergent thinking because children (6–10 years old) were less flexible in transferring their little expertise to visual domain. Further investigations are needed to explore this issue.

In addition, consistent with our hypotheses, we found that dancers were more accurate and faster in localizing the body parts as compared with non-dancers. This result confirms that the development of the topological map of the body takes advantage from dance practiced already in early childhood. More interestingly, in line with the fourth hypothesis, we found that the topological map of the body mediated the effect of the group on motor-forms divergent thinking: besides the direct effect of group on motor-forms divergent thinking, we detected a significant indirect group effect, which was mediated by performances on TMB task. Therefore, dancers were able to easily generate new movements, to provide unique and rare movements as well as to change categories of movements with respect to non-dancers, at least in part due to their improved topological map of the body.

In conclusion, in line with the worldwide health organizations, that suggested to increase levels of physical activity in school-aged children to enhance emotional, social, and cognitive functioning across their life span, the present findings support the idea to perform dance during early development because it affects many aspects of children's health (King et al., 2003) and may also have important implications for cognition, such as motor divergent thinking and creativity. The evidence that performing dance may enhance motor creativity, specifically the ability to produce motor forms, is interesting because it highlights the key role of this kind of physical activity in

children's life and the need to perform it throughout adulthood (Tucker, 2008). In addition, when improvisation is pursued, such as in modern dance (Fink and Woschnjak, 2011) or free movements with music (Campion and Letiva, 2014), it can be expected that dance produces facilitation effects also in other domains. Further studies are necessary to clarify this issue.

Regarding limitations, the absence of validation of the motor-form divergent thinking task limits the conclusions drawn by the present study. The scarce number of participants and the gender imbalance in the dance group should also be considered as possible confounding factors, even though it is noteworthy to underline that it is not easy to find children that practice classical ballet, especially boys. In future, studies with more participants based on different dance styles, equally practiced by both genders, should be pursued. In the future, given the nature of the motor-form divergent thinking task, videorecording is suggested in order to ensure that observers have observed movements properly. This would also help to evaluate movements by multiple independent judges and get the intra- and inter-agreement within and between raters, respectively. Despite these limitations, this study involves two novelties: the exploration of the relation between dance and divergent thinking in different forms (motor and visual) in children; the exploration of the extent to which the topological map of the body mediates motor divergent thinking in dancer children. Moreover, the present results also have important implications for creative dance in educational settings, because dance has to be conceived as a healing and aesthetic art (Thomson, 2011) since childhood. Following Castañer et al. (2009), it could be interesting to compare the impact of different kinds of instructions on motor creativity. Authors refer to descriptive instructions: questions using specific terminology of dance; metaphoric instructions: questions using metaphorical images; and kinesic instructions: motor examples or visual demonstrations. Descriptive and, to a lesser extent, metaphoric instructions were found to generate more motor divergence than kinesic instructions. Metaphoric instructions were found to help to understand the task and motivate participants. Therefore, Castañera and colleagues suggested to use kinesic and metaphoric instructions with beginners, and descriptive instructions with more expert dancers. According to Davenport (2006), among other teaching points, it might be also useful to translate ideas into movements of the body and develop different body movements of the same idea, draw on improvisation, learn to feel the body (e.g., energy, body parts initiation), manipulate chunks of movements, vary rhythm and length of movements, translate the notion of outside eye to inner eye to better understand what movements are expressing and develop different kinds of relationships with the co-dancers. In other words, the pedagogical value of creative dance has to be pursued using different dance styles because it has the potential to offer the opportunity to develop well-being, general cognition, and wider creativity, besides contributing to the improvement of bodily self-consciousness and motor creativity.

## ETHICS STATEMENT

The study was approved by the Ethics Committee of University of L'Aquila in accordance with the Declaration of Helsinki. A signed informed consent was obtained from parents and an assent from each child.

## AUTHOR CONTRIBUTIONS

MP has projected the study and has written the paper. LG has helped in projecting the study and has collected data.

## REFERENCES

- Alter, J. B. (1984). Creativity profile of university and conservatory dance students. *J. Pers. Assess.* 48, 153–158. doi: 10.1207/s15327752jpa4802\_8
- Alter, J. (1999). "Dance and creativity" in *Encyclopedia of creativity*. eds. M. A. Runco, and S. R. Pritzker (London: Academic Press), 496–481.
- Ayob, A., Hussain, A., Mustaffa, M. M., and Kajid, R. A. (2012). Assessment of creativity in electrical engineering. *Procedia Soc. Behav. Sci.* 60, 463–467. doi: 10.1016/j.sbspro.2012.09.407
- Baer, J. (2015). The importance of domain-specific expertise in creativity. *Roeper Rev.* 37, 165–178. doi: 10.1080/02783193.2015.1047480
- Barnikel, F., Ellbrunner, H., and Vetter, M. (2014). Teaching spatial competence today—from analogue maps to geocaching. *Cartogr. J.* 5, 257–262.
- Bassolino, M., Finisguerra, A., Canzoneri, E., Serino, A., and Pozzo, T. (2015). Dissociating effect of upper limb non-use and overuse on space and body representations. *Neuropsychologia* 70, 385–392. doi: 10.1016/j.neuropsychologia.2014.11.028
- Boccia, M., Piccardi, L., Palermo, L., Nori, R., and Palmiero, M. (2015). Where do bright ideas occur in our brain? Meta-analytic evidence from neuroimaging studies of domain-specific creativity. *Front. Psychol.* 6:1195. doi: 10.3389/fpsyg.2015.01195
- Boccia, M., Verde, P., Angelino, G., Carrozzo, P., Vecchi, D., Piccardi, L., et al. (2017). Effect of professional expertise and exposure to everyday life decision-making on moral choices. *Neurosci. Lett.* 654, 80–85. doi: 10.1016/j.neulet.2017.06.036
- Brennan, M. A. (1982). Relationship between creative ability in dance and selected creative attributes. *Percept. Mot. Skills* 55, 47–56. doi: 10.2466/pms.1982.55.1.47
- Campion, M., and Letiva, L. (2014). Enhancing positive affect and divergent thinking abilities: play some music and dance. *J. Posit. Psychol.* 9, 137–145. doi: 10.1080/17439760.2013.848376
- Cannoni, E., and Tega, A. (2009). Changes of body schema in middle childhood. [Cambiamenti dello schema corporeo nella media fanciullezza]. *Rass. Psicol* 3, 131–140. doi: 10.7379/70585
- Canzano, L., Piccardi, L., Bureca, I., and Guariglia, C. (2011). Mirror writing resulting from an egocentric representation disorder: a case report. *Neurocase* 17, 447–460. doi: 10.1080/13554794.2010.532143
- Cardinali, L., Brozzoli, C., and Farné, A. (2009). Peripersonal space and body schema: two labels for same concept. *Brain Topogr.* 21, 252–260. doi: 10.1007/s10548-009-0092-7
- Case-Smith, J., Allen, A. S., and Pratt, P. N. (2001). *Occupational therapy for children. 4th Edn.* (St. Louis: Mosby).
- Castañer, M., Camerino, O., Landry, P., and Parés, N. (2016). Quality of physical activity of children in exergames: sequential body movement analysis and its implications for interaction design. *Int. J. Hum. Comput. Stud.* 96, 67–78. doi: 10.1016/j.ijhcs.2016.07.007
- Castañer, M., Torrents, C., Anguera, M. T., Dinušová, M., and Jonsson, G. K. (2009). Identifying and analyzing motor skill responses in body movement and dance. *Behav. Res. Methods* 41, 857–867. doi: 10.3758/BRM.41.3.857
- Castañer, M., Torrents, C., Morey, G., and Jofre, T. (2012). "Appraising choreographic creativity, aesthetics and the complexity of motor responses in dance" in *Mixed methods research in the movement sciences: Case studies in sport, physical education and dance*. eds. O. Camerino, M. Castañer, and M. T. Anguera (Abingdon: Routledge), 146–176.
- Cimmino, R. L., Spitoni, G., Serino, A., Antonucci, G., Catagni, M., Camagni, M., et al. (2013). Plasticity of body representations after surgical arm elongation in an achondroplastic patient. *Restor. Neurol. Neurosci.* 31, 287–298. doi: 10.3233/RNN-120286
- Couillandre, A., Lewton-Brain, P., and Portero, P. (2008). Exploring the effects of kinesiological awareness and mental imagery on movement intention in the performance of demi-plié. *J. Dance Med. Sci.* 12, 91–98
- Damasio, A. (2010). *Self comes to mind: Constructing the conscious brain.* (New York: Pantheon Books).
- Daurat-Hmeljiak, C., Stambak, M., and Berges, J. (1978). *Il test dello schema corporeo. Una prova di conoscenza e costruzione dell'immagine del corpo [The body schema test. A test of knowledge and construction of body image].* (Firenze, Italy: Organizzazioni Speciali).
- Davenport, D. (2006). Building a dance composition course: an act of creativity. *J. Dance Edu.* 6, 25–32. doi: 10.1080/15290824.2006.10387309
- Di Russo, F., Committeri, G., Pitzalis, S., Spitoni, G., Piccardi, L., Galati, G., et al. (2006). Cortical plasticity following surgical extension of lower limbs. *NeuroImage* 30, 172–183. doi: 10.1016/j.neuroimage.2005.09.051
- Di Vita, A., Boccia, M., Palermo, L., and Guariglia, C. (2016). To move or not to move, that is the question! Body schema and non-action oriented body representations: an fMRI meta-analytic study. *Neurosci. Biobehav. Rev.* 68, 37–46. doi: 10.1016/j.neubiorev.2016.05.005
- Di Vita, A., Palermo, L., Boccia, M., and Guariglia, C. (2019). Topological map of the body in post-stroke patients: lesional and hodological aspects. *Neuropsychology*. doi: 10.1037/neu0000536 (in press).
- Di Vita, A., Palermo, L., Piccardi, L., Di Tella, J., Propato, F., and Guariglia, C. (2017). Body representation alterations in personal but not in extrapersonal neglect patients. *Appl. Neuropsychol. Adult* 24, 308–317. doi: 10.1080/23279095.2016.1174866
- Di Vita, A., Palermo, L., Piccardi, L., and Guariglia, C. (2015). Peculiar body representation alterations in hemineglect: a case report. *Neurocase* 21, 697–706. doi: 10.1080/13554794.2014.974620
- Ellbrunner, H., Barnikel, F., and Vetter, M. (2014). "Geocaching as a method to improve not only spatial but also social skills—Results from a school project" in *GI\_Forum 2014-Geospatial Innovation for Society*. eds. R. Vogler, A. Car, J. Strobl, and G. Griesebner (Berlin: Wichmann), 348–351.
- Fink, A., Graif, B., and Neubauer, A. C. (2009). Brain correlates underlying creative thinking: EEG alpha activity in professional vs. novice dancers. *NeuroImage* 46, 854–862. doi: 10.1016/j.neuroimage.2009.02.036
- Fink, A., and Woschnjak, S. (2011). Creativity and personality in professional dancers. *Pers. Individ. Differ.* 51, 754–758. doi: 10.1016/j.paid.2011.06.024
- Fonseca, C. C., Thurm, B. E., and Vecchi, R. L. (2014). Ballroom dance and body size perception. *Percept. Mot. Skills* 119, 495–503. doi: 10.2466/25.PMS.119c26z1
- Fonseca, C. C., Vecchi, R. L., and Gama, E. F. (2012). The ballroom dance influence in body perception. *Motriz: Rev. Educ. Fis.* 18, 200–207. doi: 10.1590/S1980-65742012000100020
- Fuentes, C. T., Pazzaglia, M., Longo, M. R., Scivoletto, G., and Haggard, P. (2013). Body image distortions following spinal cord injury. *J. Neurol. Neurosurg. Psychiatry* 84, 201–207. doi: 10.1136/jnnp-2012-304001

- Gondola, J. C. (1987). The effects of a single bout of aerobic dancing on selected tests of creativity. *J. Soc. Behav. Pers.* 2, 275–278.
- Green, C. S., and Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature* 423, 534–537. doi: 10.1038/nature01647
- Guariglia, C., Piccardi, L., Puglisi Allegra, M. C., and Traballasi, M. (2002). Is autotopagnosia real? EC says yes. A case study. *Neuropsychologia* 40, 1744–1749. doi: 10.1016/S0028-3932(02)00013-1
- Guilford, J. P. (1950). Creativity. *Am. Psychol.* 5, 444–454. doi: 10.1037/h0063487
- Guilford, J. P. (1967). *The nature of human intelligence*. (New York, NY: McGraw-Hill).
- Guilford, J. P., Christensen, P. R., Merrifield, P. R., and Wilson, R. C. (1978). *Alternate uses: Manual of instructions and interpretation*. (Orange, CA: Sheridan Psychological Services).
- Hayes, A. F. (2017). *Introduction to mediation, moderation, and conditional process analysis second edition. A regression-based approach*. (New York, NY: Guilford Press).
- Hillman, C. H., and Biggan, J. R. (2017). A review of childhood physical activity, brain, and cognition: perspectives on the future. *Pediatr. Exerc. Sci.* 29, 170–176. doi: 10.1123/pes.2016-0125
- Humble, S., Dixon, P., and Mpofu, E. (2018). Factor structure of the Torrance Test of Creative Thinking Figural Form A in Kiswahili speaking children: multidimensionality and influences on creative behaviour. *Think. Skills Creat.* 27, 33–44. doi: 10.1016/j.tsc.2017.11.005
- Iivonen, K. S., Sääkslahti, A. K., Mehtälä, A., Villberg, J. J., Tammelin, T. H., Kulmala, J. S., et al. (2013). Relationship between fundamental motor skills and physical activity in 4-year-old preschool children. *Percept. Mot. Skills* 117, 627–646. doi: 10.2466/10.06.PMS.117x22z7
- Kalliopuska, M. (1989). Empathy, self-esteem and creativity among junior ballet dancers. *Percept. Mot. Skills* 69, 1277–1234. doi: 10.2466/pms.1989.69.3f.1227
- Kaufman, J. C., and Baer, J. (2005). *Creativity across domains: Faces of the muse*. (Mahwah, NJ: Lawrence Erlbaum Associates).
- King, G., Law, M., King, S., Rosenbaum, P., Kertoy, M. K., and Young, N. L. (2003). A conceptual model of the factors affecting the recreation and leisure participation of children with disabilities. *Phys. Occup. Ther. Geriatr.* 23, 63–90. doi: 10.1080/J006v23n01\_05
- Lewis, R. N., and Scannell, E. D. (1995). Relationship of body image and creative dance movement. *Percept. Mot. Skills* 81, 155–160. doi: 10.2466/pms.1995.81.1.155
- Lis, A., and Tallandini, M. (1981). “Taratura italiana delle prove” in *Il test dello Schema Corporeo. Una prova di conoscenza e di costruzione dell’immagine del corpo*. eds. C. Daurat-Hmeljak, M. Stambak, and J. Bergès (Firenze: Organizzazioni Speciali).
- Marangolo, P., Piccardi, L., and Rinaldi, M. C. (2003). Dissociation between personal and extrapersonal neglect in a crossed aphasia study. *Neurocase* 9, 414–420. doi: 10.1076/neur.9.5.414.16554
- Meinz, E. J., Hambrick, D. Z., Hawkins, C. B., Gillings, A. K., Meyer, B. E., and Schneider, J. L. (2012). Roles of domain knowledge and working memory capacity in components of skill in Texas Hold’Em poker. *J. Appl. Res. Mem. Cogn.* 1, 34–40. doi: 10.1016/j.jarmac.2011.11.001
- Moraru, A., Memmert, D., and van der Kamp, J. (2016). Motor creativity: the roles of attention breadth and working memory in a divergent doing task. *J. Cogn. Psychol.* 28, 856–867. doi: 10.1080/20445911.2016.1201084
- Ozel, S., Larue, J., and Molinaro, C. (2002). Relation between sport activity and mental rotation: comparison of three groups of subjects. *Percept. Mot. Skills* 95, 1141–1154. doi: 10.2466/pms.2002.95.3f.1141
- Paillard, J. (1980). Le corps situé et le corps identifié: une approche psychophysiologique de la notion de schéma corporel. *Rev. Med. Suisse* 100, 129–141.
- Palermo, L., Di Vita, A., Boccia, M., Nemmi, F., Brunelli, S., Traballasi, M., et al. (2018). Action and non-action oriented body representations: insight from behavioural and grey matter modifications in individuals with lower limb amputation. *Biomed. Res. Int.* 2018, 1529730. doi: 10.1155/2018/1529730
- Palermo, L., Di Vita, A., Piccardi, L., Traballasi, M., and Guariglia, C. (2014). Bottom-up and top-down processes in body representation: a study of brain-damaged and amputee patients. *Neuropsychology* 28, 772–781. doi: 10.1037/neu0000086
- Palmiero, M., Di Giacomo, D., and Passafiume, D. (2016a). Can creativity predict cognitive reserve? *J. Creat. Behav.* 50, 7–23. doi: 10.1002/jocb.62
- Palmiero, M., Nakatani, C., Raver, D., Olivetti Belardinelli, M., and vanLeeuwen, C. (2010). Abilities within and across visual and verbal domains: how specific is their influence on creativity? *Creat. Res. J.* 22, 369–377. doi: 10.1080/10400419.2010.523396
- Palmiero, M., Nori, R., Aloisi, V., Ferrara, M., and Piccardi, L. (2015). Domain-specificity of creativity: a study on the relationship between visual creativity and visual mental imagery. *Front. Psychol.* 6:1870. doi: 10.3389/fpsyg.2015.01870
- Palmiero, M., Nori, R., and Piccardi, L. (2016b). Visualizer cognitive style enhances visual creativity. *Neurosci. Lett.* 615, 98–101. doi: 10.1016/j.neulet.2016.01.032
- Palmiero, M., Nori, R., and Piccardi, L. (2017). Verbal and visual divergent thinking in aging. *Exp. Brain Res.* 235, 1021–1029. doi: 10.1007/s00221-016-4857-4
- Pavlidou, E., Sofianidou, A., Lokosi, A., and Kosmidou, E. (2018). Creative dance as a tool for developing preschoolers’ communicative skills and movement expression. *Eur. Psychomot. J.* 10, 3–15.
- Pavlik, K., and Nordin-Bates, S. (2016). Imagery in dance. A literature review. *J. Dance Med. Sci.* 20, 51–63. doi: 10.12678/1089-313X.20.2.51
- Perez-Marcos, D., Martini, M., Fuentes, C. T., Bellido Rivas, A. L., Haggard, P., and Sanchez-Vives, M. V. (2018). Selective distortion of body image and asynchronous visuotactile stimulation. *Body Image* 24, 55–61. doi: 10.1016/j.bodyim.2017.11.002
- Piaget, J. (1952). *The origins of intelligence in children*. (M. Cook, Trans.). (New York, NY, US: W W Norton & Co).
- Plucker, J. A., and Beghetto, R. A. (2004). “Why creativity is domain general, why it looks domain specific, and why the distinction does not matter” in *Creativity: From potential to realization*. eds. R. J. Sternberg, E. L. Grigorenk, and J. L. Singer (Washington, DC: American Psychological Association), 153–167.
- Purcell, T. M. (1990). The use of imagery in children’s dance: making it work. *J. Phys. Educ. Rec Dance* 61, 22–23. doi: 10.1080/07303084.1990.10606436
- Runco, M. A., Millar, G., Acar, S., and Cramond, B. (2010). Torrance tests of creative thinking as predictors of personal and public achievement: a fifty-year follow-up. *Creat. Res. J.* 22, 361–368. doi: 10.1080/10400419.2010.523393
- Sacha, T. J., and Russ, S. W. (2006). Effects of pretend imagery on learning dance in preschool children. *Early Childhood Educ. J.* 33, 341–345. doi: 10.1007/s10643-006-0103-1
- Schmidt, M., Egger, F., Kieliger, M., Rubeli, B., and Schuler, J. (2016). Gymnasts and orienteers display better mental rotation performance than non athletes. *J. Individ. Differ.* 37, 1–7. doi: 10.1027/1614-0001/a000180
- Schwoebel, J., and Coslett, H. B. (2005). Evidence for multiple, distinct representations of the human body. *J. Cogn. Neurosci.* 17, 543–553. doi: 10.1162/08998929053467587
- Scibinetti, P., Tocci, N., and Pesce, C. (2011). Motor creativity and creative thinking in children: the diverging role of inhibition. *Creat. Res. J.* 23, 262–272. doi: 10.1080/10400419.2011.595993
- Silvia, P. J. (2008a). Another look at creativity and intelligence: exploring higher-order models and probable confounds. *Pers. Individ. Differ.* 44, 1012–1021. doi: 10.1016/j.paid.2007.10.027
- Silvia, P. J. (2008b). Creativity and intelligence revisited: a latent variable analysis of Wallach and Kogan (1965). *Creat. Res. J.* 20, 34–39. doi: 10.1080/10400410701841807
- Silva, P. J., Kaufman, J. C., and Pretz, J. E. (2009). Is creativity domain-specific? Latent class models of creative accomplishments and creative self-descriptions. *Psychol. Aesthet. Creat. Arts* 3, 139–148. doi: 10.1037/a0014940
- Singh, A., Uijtendewilligen, L., Twisk, J. W., van Mechelen, W., and Chinapaw, M. J. (2012). Physical activity and performance at school. A systematic review of the literature including a methodological quality assessment. *Arch. Pediatr. Adolesc. Med.* 166, 49–55. doi: 10.1001/archpediatrics.2011.716
- Spitoni, G. F., Serino, A., Cotugno, A., Mancini, F., Antonucci, G., and Pizzamiglio, L. (2015). The two dimensions of the body representation in women suffering from Anorexia Nervosa. *Psychiatry Res.* 230, 181–188. doi: 10.1016/j.psychres.2015.08.036
- Sprini, G., and Tomasello, S. (1989). *Torrance tests of creative thinking (Test di pensiero Creativo)*. (Firenze: Giunti O.S. Organizzazioni Speciali).
- Steinberg, H., Sykes, E. A., Moss, T., Lowery, S., LeBoutillier, N., and Dewey, A. (1997). Exercise enhances creativity independently of mood. *Br. J. Sports Med.* 31, 240–245. doi: 10.1136/bjism.31.3.240



- Stinson, S. W. (1993). Testing creativity of dance students in the people republic of china. *Dance Res. J.* 25, 65–68. doi: 10.1017/S0149767700008056
- Thomson, P. (2011). “Dance and creativity” in *Encyclopedia of creativity*. eds. M. A. Runco, and S. R. Pritzker (London: Academic Press), 334–350.
- Thurm, B. E., Pereira, E. S., Fonseca, C. C., Cagno, M. J. S., and Gama, E. F. (2011). Neuroanatomical aspects of the body awareness. *J. Morphol. Sci.* 28, 296–299.
- Torrance, E. P. (1987). *Guidelines for administration and scoring comments on using the Torrance Tests of Creative Thinking*. (Bensenville, IL: Scholastic Testing Service Inc).
- Tucker, P. (2008). The physical activity levels of preschool-aged children: a systematic review. *Early Child Res. Q.* 23, 547–558. doi: 10.1016/j.ecresq.2008.08.005
- Verde, P., Boccia, M., Colangeli, S., Barbetti, S., Nori, R., Ferlazzo, F., et al. (2016). Domain-specific interference tests on navigational working memory in military pilots. *Aerosp. Med. Hum. Perf.* 87, 528–533. doi: 10.3357/AMHP.4521.2016
- Verde, P., Piccardi, L., Bianchini, F., Trivelloni, P., Guariglia, C., and Tomao, E. (2013). Gender effects on mental rotation in pilots vs. nonpilots. *Aviat. Space Environ. Med.* 84, 726–729. doi: 10.3357/ASEM.3466.2013
- Vignemont, F. (2010). Body schema and body image: pros and cons. *Neuropsychologia* 48, 669–680. doi: 10.1016/j.neuropsychologia.2009.09.022
- Whitehead, M. E. (2010). *Physical literacy: Throughout the lifecourse*. (London: Routledge).
- Wyrick, W. (1968). The development of a test of motor creativity. *Res. Q.* 39, 756–765. doi: 10.1080/10671188.1968.10616608
- Zantedeschi, M., and Pazzaglia, M. (2016). Commentary: non-invasive brain stimulation, a tool to revert maladaptive plasticity in neuropathic pain. *Front. Hum. Neurosci.* 10:544. doi: 10.3389/fnhum.2016.00544
- Zeng, N., Ayyub, M., Sun, H., Wen, X., Xiang, P., and Gao, Z. (2017). Effects of physical activity on motor skills and cognitive development in early childhood: a systematic review. *Biomed. Res. Int.* 2760716, 1–13. doi: 10.1155/2017/2760716
- Zhang, L., Pi, Y., Zhu, H., Shen, C., Zhang, J., and Wu, Y. (2018). Motor experience with a sport-specific implement affects motor imagery. *PeerJ* 6:e4687. doi: 10.7717/peerj.4687

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# An Exploratory Study on Mind Wandering, Metacognition, and Verbal Creativity in Chilean High School Students

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The purpose of this study was to explore the relationship between mind wandering, metacognition, and creativity in a sample of Chilean high school students. Two hundred and twenty-eight secondary students took three self-report scales on mind wandering, metacognitive strategies and reading difficulties, two verbal creativity assessments, a test of fluid intelligence and a measure of attentional capacity. Correlational analysis, a single multiple hierarchical regression, and a three-way moderation model were performed on data. Controlling for fluid intelligence and reading difficulties, metacognition and attention predicted creativity while mind wandering did not. Additionally, a three-way interaction showed that mind wandering had a positive impact on creativity only among students with both high attention and high metacognition. These results reflect the relevance of cognitive self-regulation for creativity during the high school years. Educational implications are discussed.

**Keywords:** creativity, mind wandering, metacognition, attention, intelligence

## INTRODUCTION

The purpose of this study was to explore the relationship between mind wandering, metacognition, and creativity. Metacognition is commonly seen as a corrective to mind wandering's negative consequences (Smallwood et al., 2007; Szpunar et al., 2013). Still, both impact creativity positively. Fox and Christoff (2014) noted that both metacognitive and default mode brain networks show connectivity during the creative processes. And it has been recently proposed that both spontaneous self-generated thought and goal-directed thought play a role in creative cognition (Beatty and Jung, 2018).

Specifically, metacognition may be a factor during the creative process evaluation phase (Fox and Christoff, 2014). It may favor creativity, specially among those individuals more likely to benefit from its regulatory aspects (Kaufman and Beghetto, 2009; Kaufman et al., 2016). Kaufman and Beghetto coined the notion of metacognitive creativity to refer to “a combination of creative self-knowledge (knowing one's own creative strengths and limitations, both within a domain and as a general trait) and contextual knowledge (knowing when, where, how, and why to be creative)”

(Kaufman and Beghetto, 2013, p. 160). That said, the impact of metacognition on creativity might depend also on developmental factors. Metacognition is closely intertwined with executive function. It plays an important role in the development of a very diverse set of skills (Roebbers, 2017). Additionally, metacognitive skills do not develop at the same pace in young adolescents (van der Stel and Veenman, 2014).

Several researchers have noticed the constructive role mind wandering plays in creativity (McMillan et al., 2013). Specifically, mind wandering may provide the opportunity for insightful problem solving (Sawyer, 2011) and plays a positive role in the process of incubation (Baird et al., 2012). Experimentally induced boredom, which is thought to be related to mind wandering, is associated to creativity (Mann and Cadman, 2014). Nevertheless, mind wandering does not always favor divergent thinking (Hao et al., 2015; Smeekens and Kane, 2016).

Here, we report a study investigating how trait mind wandering and self-reported metacognitive strategies predict verbal creativity taking into account participants' performance in fluid intelligence and attentional capacity measures as well as their self-reported difficulties in reading. This study follows up other we previously developed on university and vocational students (Preiss et al., 2016). There, we found that while mind wandering positively predicted divergent thinking and creative problem solving, above the contribution of fluid intelligence and reading difficulties, metacognition did not. Yet, metacognition had a negative effect on creative problem solving only among university students. Given that the students of the current sample were younger than those of the former study we did not expect to replicate these results. Since participants in this study were high school level students, we expected that both mind wandering and metacognition will positively impact creativity, taking into consideration differences in attentional capacity, fluid intelligence and reading difficulties. Additionally, we decided to explore whether attention and metacognition moderated the impact of mind wandering on creativity. Our goal was to investigate whether students with different metacognitive and attentional profiles showed a different relation between their disposition to mind wander and their performance in our verbal creativity tasks.

## METHODS

### Participants

Two hundred and twenty-eight secondary students, from eight different schools (three private,  $n = 77$ ; three private state-funded,  $n = 81$ ; three public,  $n = 70$ ) participated in the study (age ranged from 16 to 19,  $M = 16.4$ ,  $SD = 0.63$ ; 100 women). The subjects took the assessments in one 90-min group session and during the school schedule. Approval for the project was granted by the researchers' institution ethics committee, which also examined that procedures were strictly followed. These procedures involved three steps. First, directors of participating schools provided written consent. Then, before the study was implemented, a letter to children's parents or guardians was sent explaining the nature of the study providing a method to retract permission. Finally, written consent was obtained from all participants.

## MATERIALS AND PROCEDURES

### Cognitive Measures

To measure fluid intelligence and attentional capacity we used the Fix and the Oi tests, respectively. Both measures are applied in a group format. Application times for the Fix and Oi tests are 10 and 5 min, respectively. Both tests are commercially available measures implemented and reported by the Center for the Development of Inclusive Technologies at the Pontificia Universidad Católica de Chile (CEDETI UC). The reported Cronbach's alpha by CEDETI for the Fix test is 0.85,  $p < 0.001$ , for the A form, and 0.84,  $p < 0.001$  for the B form. The reported split-half reliability for the Oi test is 0.86,  $p < 0.001$  (Riveros et al., 2015).

### Self-Report Measures

We used three self-report measures, which had been previously translated and used in Chile (Preiss et al., 2016). Students filled out Spanish versions of the Daydreaming Frequency Scale (12 items) and a scale (11 items) of metacognitive strategies taken from the Goal Orientation and Learning Strategies Survey (Dowson and McNerney, 2004). Respectively, higher scores involved higher frequency of daydreaming and higher metacognitive knowledge. To assess reading difficulties we adapted the items of the Spanish version of the Adult Reading History Questionnaire (Mourgues et al., 2014) so they suited the experience of high school age participants. Items were adapted to reflect current school experiences and introduced in present tense instead of past tense. The Likert scales were presented with verbal labels in all the values to facilitate comprehension. One item that asked about dyslexia was dropped. Higher scores reflected a higher self-report of difficulties with reading. Cronbach Alphas for the measures were as follows. For the High School Reading History Questionnaire-Spanish,  $\alpha = 0.79$ ; for the Daydreaming Frequency Scale,  $\alpha = 0.90$ ; for the Metacognition self-report,  $\alpha = 0.82$ . The average of all items was calculated to create a global score for each subject in each scale.

### Creativity Measures

To evaluate divergent thinking we used a measure based on Guilford's Alternative Uses Test (Guilford, 1967). Participants were asked to write alternative uses for a newspaper and a paperclip (3 min per object). Only appropriate uses were used to calculate the final score, discarding those that were physically impossible, needed more than one of the objects (e.g., "a chain of clips") or had an unspecific use (e.g., "to order"). Two raters assessed 38% of the newspaper answers and 30% of clips answers. The percentage of agreement between raters was acceptable for both (newspaper,  $p > 0.81$ ; clip,  $p > 0.80$ ). The scores of both tasks were added to create the final Alternative Uses score for each participant. Additionally, we employed a Spanish Compound Word Association test (Mourgues et al., 2014), inspired by an English language test (Bowden and Jung-Beeman, 2003). It assesses the ability to draw relationships between semantically distant words. The test's Cronbach's alpha, was 0.85. Total scores were the sum of correct responses.

First, the two cognitive tests were presented (Oi, FIX). Then, students answered the self-report scales (mind wandering, reading, metacognition). Finally, the two creative tests were presented (Alternative Uses and Compound Words Association Test).

## DATA ANALYSIS

Data analysis was performed using SPSS V.21. Eight participants who did not complete properly the Oi test were excluded from the regression analysis. 0.21% of participants had missing data on some items of the self-report scales. According to Little's test, the missing data could be considered missed completely at random (MCAR) in all three self-report scales. We replaced missing data using the algorithm Expectation-Maximization (Enders, 2003; Peugh and Enders, 2004). Then, we created a composite index, the Verbal Creativity Index (VCI), scaling (to a 0–10 scale) the two creativity tests results and averaging them. **Table 1** shows means, standard deviations and bivariate correlations for all variables used in the analysis.

First, we performed a correlational analysis between all variables (see **Table 1**). Later, a single multiple hierarchical regression, with mean centered variables (Aiken and West, 1991) was carried out to predict the VCI, including as predictors Fluid Intelligence (Fix), Attentional Capacities (Oi), Reading Difficulties (RD), Mind Wandering (MW), and Metacognition (Met) (see **Table 2**). Finally, following the procedure suggested by Hayes (2013), using the PROCESS package v.2.16.3, a three way moderation model was conducted. This particular model explored the moderating effect of Oi and Met, combined, on the effect of MW on VCI.

## RESULTS

The hierarchical multiple regression analysis, predicting the VCI (**Table 2**), explained 23% ( $R^2 = 0.229$ ) of the variance  $F(9,210) = 6.951, p < 0.001$ . In the first step of the model, Fix significantly predicted variance of the VCI (12%) but reading difficulties did not. In the second step, when including MW, Oi and Met, only Oi and Met accounted significantly for some variability (6%) of the VCI. In the third step of this analysis, none

of the 2-way interaction terms (MW  $\times$  Oi, MW  $\times$  Met, Oi  $\times$  Met) improved the model. However, in the fourth step, the 3-way interaction term (MW  $\times$  Oi  $\times$  Met), significantly improved the model (3%). To interpret this result, slope differences were calculated for  $-1$  SD and  $+1$  SD concerning the moderators (Dawson and Richter, 2006). MW had no significant effect on VCI when Oi was high and Met was low ( $b = -0.133, t = -0.467, p = 0.640, CI\ 95\% [-0.696, 0.429]$ ), neither when Oi was low and Met was high ( $b = -0.146, t = -0.483, p = 0.628, CI\ 95\% [-0.745, 0.451]$ ) or when Oi and Met were low ( $b = 0.112, t = 0.485, p = 0.627, CI\ 95\% [-0.344, 0.569]$ ). MW had a significant positive effect on VCI ( $b = 1.143, t = 4.044, p < 0.001, CI\ 95\% [0.586, 1.701]$ ), only when both Oi and Met were high (see **Figure 1**). When splitting the VCI into its two components (Alternative Uses and Compound Words Association Test) the interaction term only remained significant for the latter. The interaction term when predicting Alternative Uses explained only an additional 1% of the variance while this term explained an additional 3% of the variance for the Compound Words Association Test.

## DISCUSSION AND CONCLUSION

Our model showed that, controlling for fluid intelligence and reading difficulties, metacognition and attention predicted creativity while mind wandering did not. Additionally, a three-way interaction showed that trait mind wandering had a positive impact on creativity only among students with both high attention and high metacognition. Thus, our initial hypothesis was partially confirmed since metacognition but not mind wandering predicted creativity in the full sample, yet the latter did so only for students scoring high in the attention and metacognition measures. These results may be explained for the nature of our measures and our sample. Our creativity measures involve verbal skills. Since the sample was composed of high school students, their verbal skills are still developing. Thus, our creativity measures may demand a larger amount of cognitive self-regulation from high school students than from university students, making more relevant the role of attention and metacognition.

Additionally, our study makes a contribution to research on attention and creativity. A recent review suggest that whereas

**TABLE 1** | Means, standard deviations, and correlations coefficients.

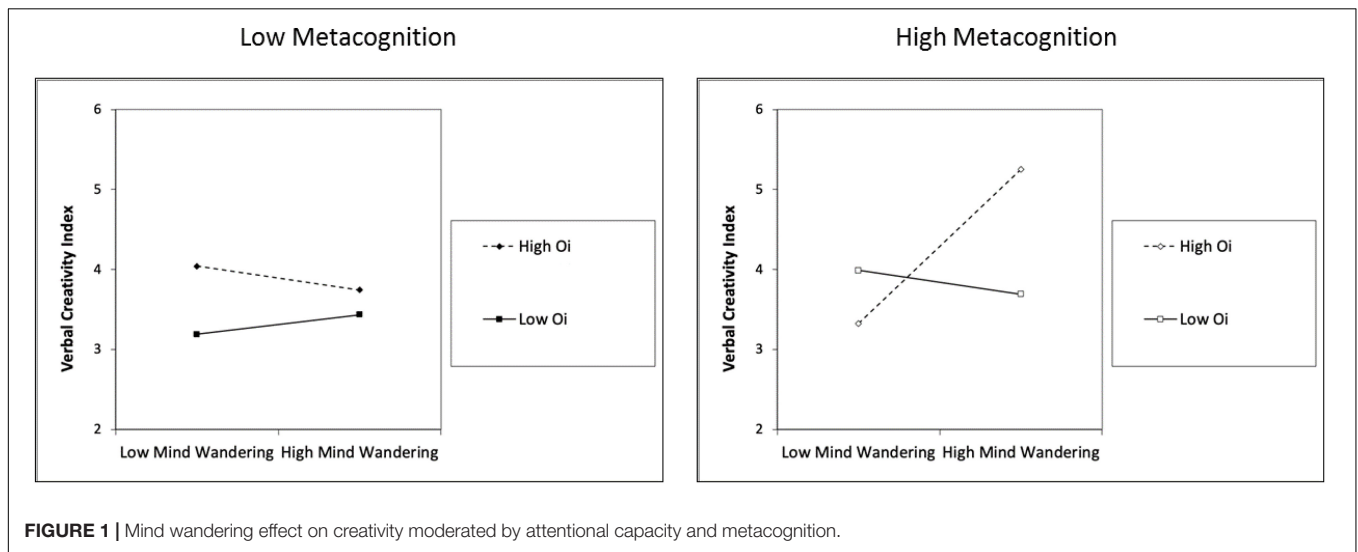
Variable	M	SD	1	2	3	4	5	6	7
(1) Fix percentile (Fix)	44.36	19.14							
(2) Oi percentile (Oi)	40.63	23.86	0.24**						
(3) Mind wandering (MW)	3.34	0.81	0.12	0.02					
(4) Reading difficulties	1.44	0.35	-0.17*	-0.08	0.20**				
(5) Metacognition (Met)	2.78	0.64	0.02	0.01	-0.12	-0.26**			
(6) Alternative Uses test	13.43	5.63	0.15*	0.17*	0.09	-0.10	0.13*		
(7) Compound Words Association test	5.66	3.15	0.41**	0.22**	0.15*	-0.16*	0.13*	0.44**	
(8) Verbal Creativity Index (VCI)	4.34	1.80	0.35**	0.23**	0.15*	-0.15*	0.16*	0.80**	0.89**

$N = 228$  for all correlations but for those including the Oi test, which consider 220 participants because of missing data for that variable. M and SD are used to represent mean and standard deviation, respectively. \* $p < 0.05$ , \*\* $p < 0.01$ .

**TABLE 2 |** Mind wandering effect on creativity moderated by attentional capacity and metacognition.

Predictors	Verbal Creativity Index			
	Step 1	Step 2	Step 3	Step 4
Constant	3.501*** (0.586) [2.345, 4.657]	3.650*** (0.601) [2.465, 4.834]	3.704*** (0.602) [2.517, 4.891]	3.840*** (0.594) [2.668, 5.012]
Fix percentile (Fix)	0.031*** (0.006) [0.019, 0.043]	0.026*** (0.006) [0.014, 0.038]	0.026*** (0.006) [0.014, 0.038]	0.028*** (0.006) [0.016, 0.040]
Reading difficulties	-0.366 (0.326) [-1.008, 0.276]	-0.317 (0.335) [-0.978, 0.343]	-0.333 (0.337) [-0.997, 0.330]	-0.486 (0.336) [-1.147, 0.176]
Oi percentile (Oi)		0.012* (0.005) [0.002, 0.021]	0.011* (0.005) [0.002, 0.021]	0.011* (0.005) [0.002, 0.020]
Mind wandering (MW)		0.280 (0.142) [-0.001, 0.560]	0.297* (0.144) [0.014, 0.580]	0.249 (0.142) [-0.031, 0.530]
Metacognition (Met)		0.435* (0.179) [0.082, 0.788]	0.409* (0.180) [0.053, 0.764]	0.364* (0.178) [0.013, 0.715]
Two-way interactions				
(MW × Oi)			0.008 (0.006) [-0.003, 0.020]	0.011 (0.006) [-0.001, 0.023]
(MW × Met)			0.284 (0.209) [-0.129, 0.696]	0.403 (0.210) [-0.011, 0.818]
(Oi × Met)			-0.001 (0.007) [-0.015, 0.014]	-0.002 (0.007) [-0.016, 0.013]
Three-way interactions				
(MW × Oi × Met)				0.026** (0.009) [0.008, 0.043]
R <sup>2</sup>	0.124	0.183	0.200	0.230
ΔR <sup>2</sup>	0.124***	0.059**	0.017	0.030**

N = 220. Unstandardized regression weights are reported. Standard Errors in parenthesis. Values in square brackets indicate the 95% confidence interval for each regression weight. \*p < 0.05, \*\*p < 0.01, \*\*\*p < 0.001.



**FIGURE 1 |** Mind wandering effect on creativity moderated by attentional capacity and metacognition.

real-life creativity is linked to leaky attention, divergent thinking is linked to flexible attention (Zabelina, 2018). Other study suggests that divergent thinking is specifically related to the capacity to update or inhibit prepotent usual responses (Benedek et al., 2014). Our results show that attention and metacognition moderate the impact of mind wandering on creativity, suggesting

that creativity may depend upon a particular combination of controlled and spontaneous thought processes.

Finally, our results are consistent with those of a study showing that metacognitive accuracy in the self-assessment of creativity is associated with higher intelligence (Karwowski et al., 2018) and with the notion that metacognition help the

creative process during the evaluation phase (Fox and Christoff, 2014). Therefore, fostering creativity in high school may entail educating metacognitive strategies and teach students how to focus their attention on the task at hand in order to improve the evaluation of their own creative products. If teachers are going to promote creativity during high school, they may need to strike a balance between upholding their students inclination to mind wander, training their students' metacognitive strategies, and promoting a good use of their attentional resources so they can fulfill their highest creative potential.

## ETHICS STATEMENT

This study was carried out in accordance with Chilean law N. 20120, which regulates research with human subjects in Chile, and with the recommendations of the Pontificia Universidad Católica de Chile's Social Sciences, Arts, and Humanities Ethics Scientific Committee. All subjects gave written informed

consent in accordance with the Declaration of Helsinki. The research procedures were approved by the Pontificia Universidad Católica de Chile's Social Sciences, Arts, and Humanities Ethics Scientific Committee.

## AUTHOR CONTRIBUTIONS

DP and VG designed the study. DO and MI implemented the study and the process of data collection. MI and HC carried out the process of data analysis. All authors contributed to writing the final version of the manuscript.

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## REFERENCES

- Aiken, L. S., and West, S. G. (1991). *Multiple Regression: Testing and Interpreting Interactions*. Thousand Oaks, CA: Sage.
- Baird, B., Smallwood, J., Mrazek, M. D., Kam, J. W. Y., Franklin, M. S., and Schooler, J. W. (2012). Inspired by distraction: mind wandering facilitates creative incubation. *Psychol. Sci.* 23, 1117–1122. doi: 10.1177/0956797612446024
- Beatty, R. E., and Jung, R. E. (2018). "Interacting brain networks underlying creative cognition and artistic performance," in *The Oxford Handbook of Spontaneous Thought. Mind-Wandering, Creativity and Dreaming*, eds K. C. R. Fox and K. Christoff (New York, NY: Oxford University Press), 275–283.
- Benedek, M., Jauk, E., Sommer, M., Arendasy, M., and Neubauer, A. C. (2014). Intelligence, creativity, and cognitive control: the common and differential involvement of executive functions in intelligence and creativity. *Intelligence* 46, 73–83. doi: 10.1016/j.intell.2014.05.007
- Bowden, E. M., and Jung-Beeman, M. (2003). Normative data for 144 compound remote associate problems. *Behav. Res. Methods Instrum. Comput.* 35, 634–639. doi: 10.3758/BF03195543
- Dawson, J. F., and Richter, A. W. (2006). Probing three-way interactions in moderated multiple regression: development and application of a slope difference test. *J. Appl. Psychol.* 91, 917–926. doi: 10.1037/0021-9010.91.4.917
- Dowson, M., and McInerney, D. M. (2004). The Development and validation of the goal orientation and learning strategies survey (Goals-S). *Educ. Psychol. Meas.* 64, 290–310. doi: 10.1177/0013164403251335
- Enders, C. K. (2003). Using the expectation maximization algorithm to estimate coefficient alpha for scales with item-level missing data. *Psychol. Methods* 8, 322–337. doi: 10.1037/1082-989X.8.3.322
- Fox, K. C. R., and Christoff, K. (2014). "Fox K.C.R., Christoff K. (2014) metacognitive facilitation of spontaneous thought processes: when metacognition helps the wandering mind find its way," in *The Cognitive Neuroscience of Metacognition*, eds S. Fleming and C. Frith (Berlin: Springer), 293–319. doi: 10.1007/978-3-642-45190-4\_13
- Guilford, J. P. (1967). *The Nature of Human Intelligence*. New York, NY: McGraw-Hill.
- Hao, N., Wu, M., Runco, M. A., and Pina, J. (2015). More mind wandering, fewer original ideas: be not distracted during creative idea generation. *Acta Psychol.* 161, 110–116. doi: 10.1016/j.actpsy.2015.09.001
- Hayes, A. F. (2013). *Introduction to Meditaion, Moderation, and Conditional Process Analysis: A Regression-Based Approach*. New York, NY: The Guilford Press.
- Karwowski, M., Czerwonka, M., and Kaufman, J. C. (2018). Does intelligence strengthen creative metacognition? *Psychol. Aesthet. Creat. Arts*. doi: 10.1037/aca0000208
- Kaufman, J. C., and Beghetto, R. A. (2009). Beyond big and little: the four C model of creativity. *Rev. Gen. Psychol.* 13, 1–12. doi: 10.1037/a0013688
- Kaufman, J. C., and Beghetto, R. A. (2013). In praise of clark kent: creative metacognition and the importance of teaching kids when (Not) to be creative. *Roep. Rev.* 35, 155–165. doi: 10.1080/02783193.2013.799413
- Kaufman, J. C., Beghetto, R. A., and Watson, C. (2016). Creative metacognition and self-ratings of creative performance: a 4-C perspective. *Learn. Individ. Differ.* 51, 394–399. doi: 10.1016/j.lindif.2015.05.004
- Mann, S., and Cadman, R. (2014). Does being bored make us more creative? *Creat. Res. J.* 26, 165–173. doi: 10.1080/10400419.2014.901073
- McMillan, R. L., Kaufman, S. B., and Singer, J. L. (2013). Ode to positive constructive daydreaming. *Front. Psychol.* 6:626. doi: 10.3389/fpsyg.2013.00626
- Mourgues, C. V., Preiss, D. D., and Grigorenko, E. L. (2014). Reading skills, creativity, and insight: exploring the connections. *Span. J. Psychol.* 17:E58. doi: 10.1017/sjp.2014.59
- Peugh, J. L., and Enders, C. K. (2004). Missing data in educational research: a review of reporting practices and suggestions for improvement. *Rev. Educ. Res.* 74, 525–556. doi: 10.3102/00346543074004525
- Preiss, D. D., Cosmelli, D., Grau, V., and Ortiz, D. (2016). Examining the influence of mind wandering and metacognition on creativity in university and vocational students. *Learn. Individ. Differ.* 51, 417–426. doi: 10.1016/j.lindif.2016.07.010
- Riveros, R., Sepúlveda, A., Figueroa, P., and Rosas, R. (2015). Memoria de trabajo y atención pueden ser usados como un nuevo test de screening de inteligencia [Working memory and attention can be used as a new test for screening intelligence]. *Papeles Invest.* 4, 1–16.
- Roebers, C. M. (2017). Executive function and metacognition: towards a unifying framework of cognitive self-regulation. *Dev. Rev.* 45, 31–51. doi: 10.1016/j.dr.2017.04.001
- Sawyer, K. (2011). The cognitive neuroscience of creativity: a critical review. *Creat. Res. J.* 23, 137–154. doi: 10.1080/10400419.2011.571191
- Smallwood, J., Fishman, D. J., and Schooler, J. W. (2007). Counting the cost of an absent mind: mind wandering as an underrecognized influence on educational performance. *Psychon. Bull. Rev.* 14, 230–236. doi: 10.3758/BF03194057
- Smeekens, B. A., and Kane, M. J. (2016). Working memory capacity, mind wandering, and creative cognition: an individual-differences investigation into the benefits of controlled versus spontaneous thought. *Psychol. Aesthet. Creat. Arts* 10, 389–415. doi: 10.1037/aca0000046

- Szpunar, K. K., Moulton, S. T., and Schacter, D. L. (2013). Mind wandering and education: from the classroom to online learning. *Front. Psychol.* 4:495. doi: 10.3389/fpsyg.2013.00495
- van der Stel, M., and Veenman, M. V. J. (2014). Metacognitive skills and intellectual ability of young adolescents: a longitudinal study from a developmental perspective. *Eur. J. psychol. Educ.* 29, 117–137. doi: 10.1007/s10212-013-0190-5
- Zabelina, D. L. (2018). "Attention and creativity," in *The Cambridge Handbook of the Neuroscience of Creativity*, eds R. Jung and O. Vartanian (Cambridge, MA: Cambridge University Press), 161–179. doi: 10.1017/9781316556238.010

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# Creativity Style and Achievements: An Investigation on the Role of Emotional Competence, Individual Differences, and Psychometric Intelligence

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Psychometric and emotional intelligence are considered as two separate theoretical constructs, although each one has been found to correlate to a certain degree with measures of creativity. The aim of the present study was to analyze whether individual differences such as age and gender, together with psychometric intelligence and emotional competence (EC) predicted creativity. We selected a sample of 376 participants aged 12–88 (mean age = 30.28 years,  $SD = 19.09$  years; 224 females) to evaluate relationships between these constructs across lifespan. Participants were administered the Kaufman Brief Intelligence Test-2, the Short Profile of EC, the Creativity Style Questionnaire Revised (CSQ-R) and the Creative Achievement Questionnaire (CAQ). *T*-test on gender differences evidenced that males had higher creativity achievements compared to females. A path analysis was applied to examine the relationships between the CAQ and CSQ-R scores as dependent variables and the potential predictors assessed. Results showed that CSQ-R was significantly predicted by interpersonal emotional competence and marginally by educational level ( $p = 0.058$ ) and intrapersonal emotional competence ( $p = 0.051$ ). On the other hand, the CAQ score was significantly predicted by gender, age, and composite IQ. Discussion is focused on possible theoretical implications.

**Keywords:** creativity, age factors, intelligence, individual difference, emotional competence

## INTRODUCTION

A long tradition of research suggests that creativity is related to general cognitive abilities (e.g., Guilford, 1967; Kaufman and Plucker, 2011) and increasing evidence underlines a link between creativity and emotional intelligence (EI) (e.g., Guastello et al., 2004; Sánchez-Ruiz et al., 2011). Psychometric and EI are considered as two separate theoretical constructs (Mayer et al., 1999) although each one has been found to correlate to a certain degree with measures of creativity. Whereas some studies investigated dyadic relationships amongst these three competencies (i.e., creativity, psychometric intelligence, and EI), lack



of evidence is available as regards how these constructs are related to one another. The present study aims to investigate the relation between psychometric intelligence, EI and creativity, taking into account demographic variables, such as gender and age. In the following sections, we will briefly define these constructs considering their evolution over the life-course and analyze previous studies which investigated relations amongst them.

## Creativity, Psychometric Intelligence, Emotional Intelligence, and Demographical Variables

It is beyond the scope of the present study to summarize the huge amount of studies that tried to define these three constructs, but all such attempts evidenced that creativity, psychometric intelligence and emotional competence (EC) cannot be reduced to single factors and need to be considered as multidimensional competencies.

Creativity is thought to derive from the interaction between the individual's attitudes, cognitive processes and environment and this interaction produces something both novel and useful within a given social context (Plucker et al., 2004). The creativity literature has seen convergence on some core issues. For example, a basic definition of creativity has pointed out the capacity to produce ideas and products that are both original and useful or task appropriate (Plucker et al., 2004; Kaufman, 2016). However, because of the complexity of the construct, creativity has been studied at different conceptual levels (Guilford, 1967; Rhodes, 1987; Simonton, 2000; Kaufman and Beghetto, 2009), thus considering creative achievement, creativity style, and creative potential. Creative achievement is the actual realization of this potential and refers to the visible results reached by individual in the course of life (Carson et al., 2005). For the assessment of creative achievement self-report measures are generally used (e.g., Creative Achievement Questionnaire – CAQ; Carson et al., 2005) investigating the level of creativity in relation to different domains.

Both classic (i.e., Feist, 1998) and more recent works (Kaufman et al., 2016) have shown that not only cognitive characteristics, but also personality traits predict creative potential and achievement. One such an example is the openness trait, which is one of the most consistent personality predictors of creativity (e.g., Silvia et al., 2014; Conner and Silvia, 2015; Karwowski and Lebeda, 2015; Forthmann et al., 2018). Moreover, researchers have recently begun to study “how” or “in what way” people exhibit their creativity (Houtz et al., 2010), that is their creativity style. Creative style refers to beliefs (e.g., unconscious beliefs, inspiration, and insight) and to the use of particular strategies (e.g., brainstorming, taking a walk, and taking notes) that accompanies creative work. Creativity style can be measured through the Creativity Style Questionnaire (Kumar and Holman, 1989) or its revised form (QSC-R, Kumar et al., 1997).

Finally, a number of studies focused on divergent thinking (DT), as candidate predictor of creative potential. DT is generally measured with tests such as the Torrance Tests of Creative Thinking, (Torrance et al., 1966) that require to produce different responses for each specific item, with the aim to assess fluency,

flexibility, originality and elaboration of ideas. However, there are many arguments (e.g., Weisberg, 2006) suggesting that DT tests should not be considered measures of creative potential but rather “estimates of the potential for creative problem solving. DT is not synonymous with creativity” (Runco and Acar, 2012, p. 72). Creative potential, usually defined as the human's ability to do something new and useful (Sternberg and Lubart, 1999), is more than DT alone (Runco, 1991; Baer, 1993). Indeed, it also involves deductive and inductive thinking (Dunbar, 1997; Vartanian et al., 2003; Weisberg, 2006) and, as outlined in the work of Getzels and Csikszentmihalyi (1976) and reinforced in the later literature referring to the nature of creative thought, the ability to use specific problem solving strategies (Finke et al., 1992; Runco, 1994) and to generate novel and appropriate solutions and outcomes. The present study did not included measures of DT but specifically focused on creative style and creative achievement measures.

The relationship between creativity and intelligence and the role played by intelligence in creativity is one such continuing research question: theoretical mechanisms of the links between intelligence and creativity are still up for debate, specifically the nature of this relationship. Nowadays, the most accredited taxonomy of intelligence is that proposed by CHC theory (Cattell–Horn–Carroll, Alfonso et al., 2005), a three stratum hierarchical model which includes a general (g) factor and a set of broad abilities which, in turn, include a subset of narrow abilities. Psychometric intelligence can be considered a relatively stable trait across the human lifespan (Deary et al., 2010), although a decline in intelligence scores in elderly populations has been reported (Miller et al., 2009; Wisdom et al., 2012), associated with reduced cognitive control (Craik and Byrd, 1982; Manard et al., 2014), and impoverished working memory functioning (Sander et al., 2012). Considering this point of view, creative ability is conceptualized as a part of intelligence. Although some studies have focused on fluid intelligence (e.g., Batey et al., 2010), recent investigations have followed the CHC model's placement of creativity, which is in fluid intelligence, or long-term storage and retrieval (Kaufman, 2015). Fluency (i.e., the ability to quickly recall a large number of things) has been found (Unsworth et al., 2010) to be primarily accounted for by working memory capacity (which is part of fluid intelligence) and by vocabulary knowledge (crystallized intelligence); its connection with DT, that is creativity, is certainly straightforward (Kaufman et al., 2011; Silvia et al., 2013).

The vast majority of past studies focus on creativity and changing across lifespan in relation to intelligence. Specifically, it has been found that creativity increases from childhood to adulthood (Smith and Carlsson, 1983, 1985), and more specifically when considering creativity tasks involving real-world problems (Wu et al., 2005). Indeed, the age differentiation hypothesis (Anastasi, 1958; for a review see Blum and Holling, 2017) proposes that the structure of cognitive ability varies across respondent age. A prominent theory about the structural development of cognitive abilities claims dedifferentiation in old age (Baltes et al., 1999). According to this dedifferentiation hypothesis, the g-factor explains more variance with increasing age. Moreover, the dynamic differentiation theory states that

the development of cognitive abilities in old age is mainly influenced by common sources, resulting in higher correlations between different cognitive abilities. In contrast, the non-dynamic dedifferentiation theory states that changes in different cognitive abilities are due to a common developmental cause which influences all cognitive abilities with an invariant strength with increasing age (for a review see Hartung et al., 2018). We focused on the relation between intelligence and creativity across lifespan. Considering the elderly, Zhang and Niu (2013) found a decline in creativity, while Ueno et al. (2015) found that, in elderly subjects, higher individual creativity, but not IQ scores, were significantly related with EEG complexity of resting state, which is thought to reflect neural network characteristics. In a similar vein, Jung et al. (2010) found an inverse relationship between cortical thickness and the creativity measures, as measured by the CAQ (Carson et al., 2005), thus suggesting that the network was not limited to a specific brain region, nor to the “more is better” notion (Jung et al., 2005) that is often invoked in explaining life-course trajectories. Considering the accepted progressive thinning of cortical areas in the elderly (Fjell et al., 2009), the results presented by Jung et al. (2005) and Ueno et al. (2015) would allow to hypothesize that creativity does not necessarily decrease according to cognitive decline.

Another issue considered by researchers is the creative potential in relation to demographic variables such as gender differences. There are many studies on gender differences, some using very different methodologies, techniques, and populations (for a review see Baer and Kaufman, 2008). Research on the existence and/or direction of gender differences in creativity has produced mixed and inconsistent findings. Some researchers find men as more creative (e.g., Schmidt and Sinor, 1986), whereas others find higher scores in women (e.g., Amabile, 1983; Richardson, 1986). Others still find no gender differences at all (e.g., Dudek and Verreault, 1989; Paguio and Hollett, 1991). These results could be explained by taking into account the type of creative tasks or questionnaire people have to solve or fill in (Hardy and Gibson, 2015). Considering this aspect, men appear more creative when using measures of creative accomplishment (Simonton, 1994; Piirto, 2004), whereas women appear more creative when using measures of creative potential. Collectively, these findings suggest that gender differences may exist at the measurement level for creativity. Different theories have been developed to explain gender differences in creativity. For example, Abra and Valentine-French (1991) suggested that “creative achievement depends on both biological and environmental factors... [and] because men and women differ in both factors, either or both could have produced the achievement difference” (p. 235). Biological theories of gender differences in creativity are theories that examine the theory that androgynous males and females may be more creative than their less androgynous counterparts. As an example, one currently popular explanation is proposed by Pinker and Spelke (2005). These authors suggest that when mean levels are identical on a given trait, men and women often have different normal curves, with men’s curves often being flatter. “[E]ven in cases where the mean for women and the mean for men are the same, the fact that men are more variable implies that the proportion of

men would be higher at one tail, and also higher at the other. As it’s sometimes summarized: more prodigies, more idiots” (Pinker and Spelke, 2005, para. 24). Other theories interpreted gender differences considering differences in development in relation to task demand. Hutt and Bhavnani (1976) explained these differences by the fact that preschool girls, who are more linguistically and socially competent than preschool boys, may engage in more symbolic and therefore covert role-play than boys, and that this kind of imaginative activity would not be very obvious to an observer. It should be noted that the behavioral differences observed by Hutt and Bhavnani (1976) are consistent with gender stereotypes. More recently, Baer and Kaufman (2008) proposed a new theoretical framework: the APT model of creativity, which is a hierarchical model that considers different levels of explanation to interpret gender differences. The first level (*initial requirements*) includes things that are necessary (but not sufficient) for any type of creative production; the second (*general thematic areas*) is referred to those skills, traits, and knowledge that promote creativity; the third level is characterized by *domains* where there are limited factors that promote creativity; and finally *microdomains*, each with its own very specialized knowledge that one must master to make creative contributions, such as biology.

The authors suggested that there seems to be some general factor at work that is limiting female accomplishment: the primary general factor being the Initial Requirement of environment. The environments in which male creators work are generally more conducive to creative accomplishment than those of female creators, allowing men to express their creative abilities more regularly than women. These differences can also be found in the opportunities available to male and female children and adults, and differences in the kinds of experiences women and men are likely to have.

Finally, with reference to EI, this can be defined as the ability to perceive, recognize and label emotions accurately, to use emotions to ameliorate reasoning, and to regulate one’s own emotions (Mayer and Salovey, 1997). Many efforts have been devoted to possibly consider EI as a standard intelligence (McCann et al., 2014) and also in these domains hierarchical models have been proposed. The most influential is the four factors model (Mayer et al., 2002) which includes accurate perception and expression, facilitation (use of emotion to aid problem solving), understanding (of the relation between emotions and contexts), and management (regulation of one’s own and others’ emotions). Although EI is related to psychometric intelligence, it is not included in the CHC model and many evidences suggest that it is a separate construct (e.g., McCann et al., 2014). Some studies have recently tested models in which established factors of emotional processing were regressed into factors representing interindividual variance in cognitive functioning (Mathersul et al., 2008; Adolphs, 2009; Wilhelm et al., 2010) with mixed results. A study by Hildebrandt et al. (2015) addressed this issue by means of a latent variable modeling on selected measures of cognition, emotion recognition and emotion perception. These authors found limited uniqueness in emotion expression perception and evidenced that most variance in this ability can be accounted for by face identity processing and

general cognitive skills (figural reasoning, working memory, and immediate and delayed memory).

The effects of aging on EC have been studied by means of self-reported questionnaires. For example, in a recent study (Cabello et al., 2014), a lower level of EI was reported in older people compared to younger people in all dimensions of the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT, Mayer et al., 2002) (perceiving, facilitating, and understanding emotions) except for the managing emotions subscale. They also found that EI was significantly correlated with educational level, and that this variable predicts several dimensions of EI over and above the effects of gender and age. These results seem to be in line with neurophysiological evaluations of emotion recognition. For example, a recent meta-analysis suggests a decline in emotion recognition in the elderly (Ruffman et al., 2008) and other studies reported young-old differences in recognizing complex emotions and mental states in the eyes (Phillips et al., 2002), or in reduced physiological responses to emotion stimuli (Tsai et al., 2000; Kunzmann et al., 2005). However, these trends do not necessarily legitimate to conclude that older people are less emotionally competent than younger people. Their worse performance in emotion recognition tasks might be due to confounding variables such as the nature of the experimental tasks, which are often characterized for presenting non-spontaneous facial expression of emotions and may be highly demanding in the cognitive load required. Moreover, as suggested by Ruffman et al. (2008), older adults might process emotional information not necessarily worse, but just differently than younger adults. In this line a study by Tessitore et al. (2005) suggested that elderly subjects might engage a more distributed neocortical network during the perceptual processing of emotional facial expressions, thus implementing compensatory responses and/or alternative strategies in processing emotions, as the elderly appear to engage cognitive/linguistic systems (e.g., Cabeza et al., 1997; Gunning-Dixon et al., 2003) in the context of a decrease in amygdala activity (e.g., Iidaka et al., 2002; Gunning-Dixon et al., 2003).

## Relationships Between Creativity, Psychometric Intelligence, and Emotional Intelligence

As previously mentioned, creativity has been studied both in relation to general cognitive ability and EI. Creativity seems to represent the intersection where general cognitive ability and EI meet each other.

Many studies have investigated the relationship between psychometric intelligence and creativity. It is known that many processes involved in the development of creativity actually represent skills included in the traditional assessment of cognitive functioning. For example, problem solving, analogic thought, working memory, sustained attention, cognitive flexibility, temporal organization, planning, and evaluation of information adequacy, would appear to be the main cognitive activities activated when searching for an original idea (Dietrich, 2004), and most of them refer to the role of the prefrontal cortex (Carlsson et al., 2000; Abraham et al., 2012). It has been suggested that intelligence predicts creativity especially when

it is tested through DT tasks, which explicitly require the subject to be creative at that specific time, in order to evaluate fluency and originality. In contrast, using self-report measures, correlations are weaker with cognitive variables and stronger with other variables, such as personality (Batey et al., 2010). These findings have made it possible to better highlight the contradictory relationship between intelligence and creativity: cognitive performance tasks and DT ability evidently cannot alone explain the wide variety of creative performances (Batey and Furnham, 2006). The relationship between intelligence and creativity is seen in terms of the threshold hypothesis (Jauk et al., 2013). The basic idea behind the threshold hypothesis is that to reach high levels of creativity, high or at least above-average intelligence is required. Guilford (1981) first suggested the existence of a non-linear relationship between the two constructs, with the presence of a high correlation between IQ and creativity scores for an IQ below 120, and a low correlation for an IQ above the average. Guilford explained this discrepancy by referring to the way in which individuals differ in the use of divergent or convergent thinking for problem solving tasks. Subjects with an IQ below 120 would use most of their divergent abilities to arrive at a plausible solution, while those with a higher IQ would rely more on their stable convergent thinking skills. Recent evidence (Jauk et al., 2013) suggested that the threshold hypothesis might vary according to the specific domain of creativity investigated. The threshold of 120 seems to be valid when the ideational originality is more demanding, whereas an IQ of 100 was found to be sufficient for less demanding tasks and an IQ of 85 was found to fit the threshold for a simply quantitative measure of creative potential (i.e., ideational fluency). On the contrary, no threshold was found for creative achievement, i.e., creative achievement benefits from higher intelligence even at fairly high levels of intellectual ability. Finally, intelligence seems to be necessary but not sufficient for creativity and for this reason the need arises to consider also non-cognitive variables, especially emotional and personality aspects (Batey and Furnham, 2006). Recently, Karwowski et al. (2016), in eight studies using different measures of intelligence (i.e., Raven Matrices – Raven, 2000; the Baddeley's Grammatical Reasoning Test – Baddeley, 1968; Hunt, 2010) and creativity (i.e., Test of Creative Thinking–Drawing Production/Fluency Production/Originality Production – Urban and Jellen, 1996; Test of Creative Imagery Abilities – Jankowska and Karwowski, 2015) observed a consistent pattern that supports the necessary-but-not-sufficient relationship between these two constructs. The authors concluded that although evidence concerning the threshold hypothesis on the creativity–intelligence relationship is mixed, the “necessary condition hypothesis” is clearly corroborated by the results of appropriate tests (see also Karwowski et al., 2017).

In this regard, some studies addressed the issue of the relation between EI, also referred to as EC, and creativity. One line of research investigated the relation between psychopathology and creativity, with contrasting results. Some authors (Andreasen, 1997) found that creative writers and their relatives reported higher percentages of mood disorders compared to controls. Others found not consistent relations between mood disorders

and creativity (Waddell, 1998). In this line, Smith and van der Meer (1994) found that patients with psychosomatic disorders who scored higher on standardized measures of creativity produced a greater range of emotional responses, while those with a more restricted pattern of emotional expression scored lower on creativity measures. A study on healthy undergraduate students reported that self-report measures of creativity (specifically, emotional creativity) were not directly related to creative behavior (Ivcevic et al., 2007) but Sánchez-Ruiz et al. (2011) found that EI related to creativity. Possibly EI might be a trait that enhances creativity under specific circumstances, for example when creative activities require the management of emotion (such as in performing) or, alternatively, EI might counterbalance mood disorders in improving creative production (Guastello et al., 2004) because people who possess this skill are more likely to understand their psychological difficulties and direct them into something positive.

In summary, a number of evidences seem to suggest that creativity correlates with both psychometric intelligence and EC but, to the best of our knowledge, no study has directly combined the differential contribution of age, gender, general intelligence, and EC on creativity. Moreover, educational level is considered one of the most influent mediators of lifespan trajectories in the variables considered, thus we included it as a possible predictor of creativity scores.

The aim of the present study was therefore to investigate predictors of creativity, both in terms of style and achievement. In particular, we examined the differential impact of socio-demographic aspects, such as age, gender, and education, and that of psychometric intelligence and EI.

Based on previous literature we expected a significant impact of age and psychometric intelligence on both creativity measures, with a negative relationship concerning age and a positive one for IQ. We also expected EI to further contribute to creativity, over and above intelligence and age. Moreover, we expected gender to have a different role in the creativity dimensions examined, with men showing higher achievements and women better creativity styles.

## MATERIALS AND METHODS

### Participants

The present study was designed in accordance with the ethical principles for human experimentation in the Declaration of Helsinki and with the local ethics committee. All adult participants signed a written and informed consent form before the study began. All parents of children involved in the study gave their written and informed consent. None of the participants had a history of neurological or psychiatric disease, which was confirmed during an informal interview carried out before the test phase. We recruited 376 participants aged 12–88 (aged  $M = 30.28$  years,  $SD = 19.09$  years) constituted by 152 males and 224 females (age males,  $M = 29.6$  years,  $SD = 19.32$  years; age females,  $M = 30.7$  years,  $SD = 18.83$  years). All participants had normal or corrected-to-normal vision. The

sample was selected based on demographic characteristics (educational level) of the Italian population given by ISTAT<sup>1</sup>.

### Materials

#### Creativity Style Questionnaire Revised (CSQ-R; Kumar et al., 1997)

The questionnaire was developed to measure beliefs and strategies regarding creativity. Participants responded to each question on a 5-point Likert scale (ranging from 1 = strongly agree to 5 = strongly disagree). The questionnaire included 78 items falling into seven subscales: belief in unconscious process (e.g., creative ideas occur to me without even thinking about them); use of techniques (e.g., I often let my mind wander to come up with new ideas), use of other people (e.g., I am at my creative best when I work alone); final product orientation (e.g., I usually have a lot of workable ideas); environmental control (e.g., I typically have background music when I am engaged in creative work); superstition (e.g., I have a favorite amulet or piece of clothing that I wear when I am engaged in creative work); and use of sense (e.g., I tend to use my sense of touch in my creative work). Cronbach's alpha estimated for the seven scales ranged from 0.45 to 0.81, with a median of 0.74. We decided to focus on the total score of the CSQ-R, which is given by the sum of each subscale score, in order to have a quantitative total score to be used in regression and correlational analyses.

#### Creative Achievement Questionnaire (CAQ; Carson et al., 2005)

The CAQ is a self-report checklist consisting of 96 items, divided into three parts. Part One lists 13 different areas of talent, including the 10 domains of artistic and scientific creativity, and three additional domains: individual sports, team sports, and entrepreneurial ventures. Part Two lists concrete achievements in the 10 standard domains of artistic and scientific endeavor (visual arts, music, dance, creative writing, architectural design, humor, theater and film, culinary arts, inventions, and scientific inquiry). The participant is asked to place a checkmark next to the items describing his or her accomplishments. Each domain includes eight ranked questions weighted with a score from 0 to 7. Each domain consists of a “no achievement” item with a weight of zero points (“I have no training or recognized talent in this area”), a “training” item with a weight of one point (“I have taken lessons in this area”), and six additional items of ascending achievement (“I have won a national prize in the fields of science or medicine”). Part Two yields a separate domain score for each of the 10 domains of assessed creative achievement as well as a Total Creative score. Part Three consists of three questions asking the participant to indicate how others perceive him or her, relative to creative characteristics. The questionnaire shows a good test-retest reliability ( $r = 0.81$ ) and internal consistency reliability (Cronbach's alpha = 0.96). We decided to focus only on the total score of the CAQ.

<sup>1</sup><http://dati.istat.it/?lang=it>

## The Short Profile of Emotional Competence (S-PEC; Mikolajczak et al., 2014)

The S-PEC is a 20-item tool that measures 10 dimensions, namely, identification of one's own emotions (Identification-self; e.g., When I am touched by something, I immediately know what I feel); identification of others' emotions (Identification – others; e.g., I am good at sensing what others are feeling); understanding of own emotions, (Understanding – self; e.g., I do not always understand why I respond in the way I do); understanding of others' emotions (Understanding – others; e.g., I do not understand why the people around me respond the way they do); expression of own emotions (Expression – self; e.g., I find it difficult to explain my feelings to others even if I want to); listening to others' emotions (Listening – others; e.g., Other people tend to confide in me about personal issues); regulation of own emotions (Regulation – self; e.g., When I am angry, I find it easy to calm myself down); regulation of others' emotions (Regulation – others; e.g., When I see someone who is stressed or anxious, I can easily calm them down); use of own emotions (Use – self; e.g., I never base my personal life choices on my emotions); and use of others' emotions (Use – others; e.g., I can easily get what I want from others). These dimensions have been found to load on two higher-order factors: intra-personal EI and interpersonal EI, forming together a single EI score. Participants responded to each question on a 5-point Likert scale (ranging from 1 = strongly agree to 5 = strongly disagree). The questionnaire showed moderate to strong correlations between each subscale and the global score (from 0.38 to 0.69), moderate to strong correlations between intrapersonal subscales and the intrapersonal factor (from 0.43 to 0.73) and strong correlations between the interpersonal subscales and the interpersonal factor (0.62–0.74). Intrapersonal EC and Interpersonal EC were moderately correlated ( $r = 0.57$ ).

## Kaufman Brief Intelligence Test, Second Edition (KBIT-2; Kaufman and Kaufman, 2005; Bonifacci and Nori, 2016)

The Kaufman Brief Intelligence Test, Second Edition (KBIT-2) is a brief, individualized test for measuring verbal and nonverbal intelligence in children and adults from the ages of 4 years through 90 years. It has three subtests, two (vocabulary and riddles) are included in the Verbal IQ score and a Matrices subtest constitutes the Nonverbal scale. Raw scores are converted into standardized scores (mean = 100,  $SD = 15$ ). The internal

consistency, specifically the split-half reliability, for the Verbal Scale and Composite IQ was high ( $M = 0.91$  and  $0.93$ ; respectively). The split-half reliability for the Nonverbal Scale decreased to  $0.80$  and  $0.90$ . The adjusted test-retest reliability for the Verbal Scale was a mean of  $0.91$ , the mean for the Nonverbal Scale was  $0.83$ , and the mean for the Composite IQ was  $0.90$ .

## Background Information

Participants were asked to fill out a short questionnaire concerning socio-demographic information, including questions on educational level, age and gender. Other questions served to identify exclusionary criteria, such as questions about physical impairments. For educational level we considered the years of education.

## Procedure

Participants were recruited through advertisements in adult education centers and social centers or through local schools across Italy and they agreed to participate in the study voluntarily. Exclusionary criteria were physical or psychological disabilities that would compromise their ability to fill out the battery described above. Participants took part in the experimental session individually, filling in the questionnaire and KBIT-2. The order of tasks presentation was randomized. The experiment lasted approximately 1 h and 30 min.

## RESULTS

The first set of analyses was carried out using the SPSS package (version 21.0; IBM, United States). First, we performed a bivariate correlation of the main variables included in the study. In **Table 1** the Pearson indexes are reported. Regarding gender, we classified male as  $-1$  and female as  $1$  as suggested by Howitt and Cramer (2011). Descriptives and  $t$ -test results about gender differences are reported in **Table 2**. All scores, except CAQ, were distributed normally (asymmetry between  $-2$  and  $+2$ ; Trochim and Donnelly, 2006). CAQ scores were log-transformed and this allowed to have not-skewed data (Bland et al., 2013).

Results from the correlation analyses evidenced, in particular, that Interpersonal, but not Intrapersonal, EC was significantly related to both creativity style and achievement. The relationship

**TABLE 1** | Correlations between demographic variables (age and educational level), emotional competence (intrapersonal and interpersonal), and creativity (style and achievement).

	Age	Educational level	IQ composite	Intrapersonal EC	Interpersonal EC	CSQ-R score	CAQ score
Age	—	−0.38**	0.01	0.02	−0.13*	−0.11*	−0.20**
Educational level	—	—	0.15**	0.03	0.19**	0.14**	0.07
IQ composite	—	—	—	0.02	0.07	−0.00	0.14**
Intrapersonal EC	—	—	—	—	0.40**	−0.03	0.06
Interpersonal EC	—	—	—	—	—	0.15**	0.12*
CSQ-R score	—	—	—	—	—	—	.08

\* $p < 0.05$  and \*\* $p < 0.01$ .

**TABLE 2** | Mean and SD values for males and females together with *p*-values and effect size (Cohen's *d*) referred to gender differences.

	Males		Females		<i>t</i> ( <i>df</i> 374)	<i>p</i>	Cohen's <i>d</i>
	Mean	SD	Mean	SD			
Age	29.68	19.33	30.85	18.87	-0.586	0.55	0.06
Educational level	3.07	1.02	3.07	1.03	0.009	0.99	0.00
IQ composite	103.22	14.6	100.9	14.86	1.574	0.11	0.17
Intrapersonal EC	31.65	5.07	32.58	5.35	-1.682	0.09	0.18
Interpersonal EC	32.22	5.67	33.35	5.69	-1.896	0.06	0.20
CSQ-R score	241.69	23.1	242.5	24.7	-0.321	0.75	0.03
CAQ score	6.79	10.45	4.62	4.17	2.797	< 0.05	0.3

between the two components of EC was significant, but with medium effect size, suggesting that the two dimensions are not overlapped. Furthermore, IQ was related only to creative achievements but not to EC and creative style.

## Gender Differences

We ran a set of *t*-tests with gender (males and females) as independent variable and educational level, EC (intrapersonal and interpersonal) and creativity (style and achievement) as dependent variables. **Table 2** reports the mean and SD values together with *p*-values and effect size (Cohen's *d*). The two groups differed only in CAQ scores, with males reaching higher creativity achievements compared to females.

## Concurrent Predictors of CAQ and CSQ-R Scores

A path analysis was applied using MPlus software (Muthén and Muthén, 1998–2010). Path analysis was used to examine the relationships between the CAQ and CSQ-R scores as dependent variables and the potential predictors assessed, which included gender, age, educational level, composite IQ, intrapersonal and interpersonal EC. Multiple indices were used to evaluate model fit: Chi-square, the root mean square error of approximation (RMSEA), the comparative fit index (CFI), the Tucker–Lewis index (TLI), and the standardized root mean squared residual (SRMR). A non-significant Chi-square, and TLI and CFI values equal to or higher than 0.90 indicate an acceptable model fit; RMSEA and SRMR values close to, respectively, 0.06 and 0.08 or lower indicate an acceptable fit (Hu and Bentler, 1999).

The model's fit indexes were the following:  $\chi^2(1) = 1.07$ ,  $p = 0.3$ , RMSEA = 0.014 (90 % CI = 0.00, -0.138); CFI = 0.998; TLI = 0.976; SRMR = 0.008. Considering Hu and Bentler's (1999) criteria, the model has good fit indices. The proportion of explained variance for CAQ and CSQ-R scores was relatively low (8.5 and 5.1%, respectively).

**Figure 1** describes the model fitted to the data obtained, and it is possible to observe that CSQ-R was significantly predicted by interpersonal EC and marginally by educational level ( $p = 0.058$ ) and intrapersonal EC ( $p = 0.051$ ). On the other hand, the CAQ score was significantly predicted by gender, age and composite IQ.

## DISCUSSION

The present study focused on an investigation about predictors of creative achievements and creative style, and took into account demographical variables such as age, gender, and educational level together with measures of psychometric intelligence and EC.

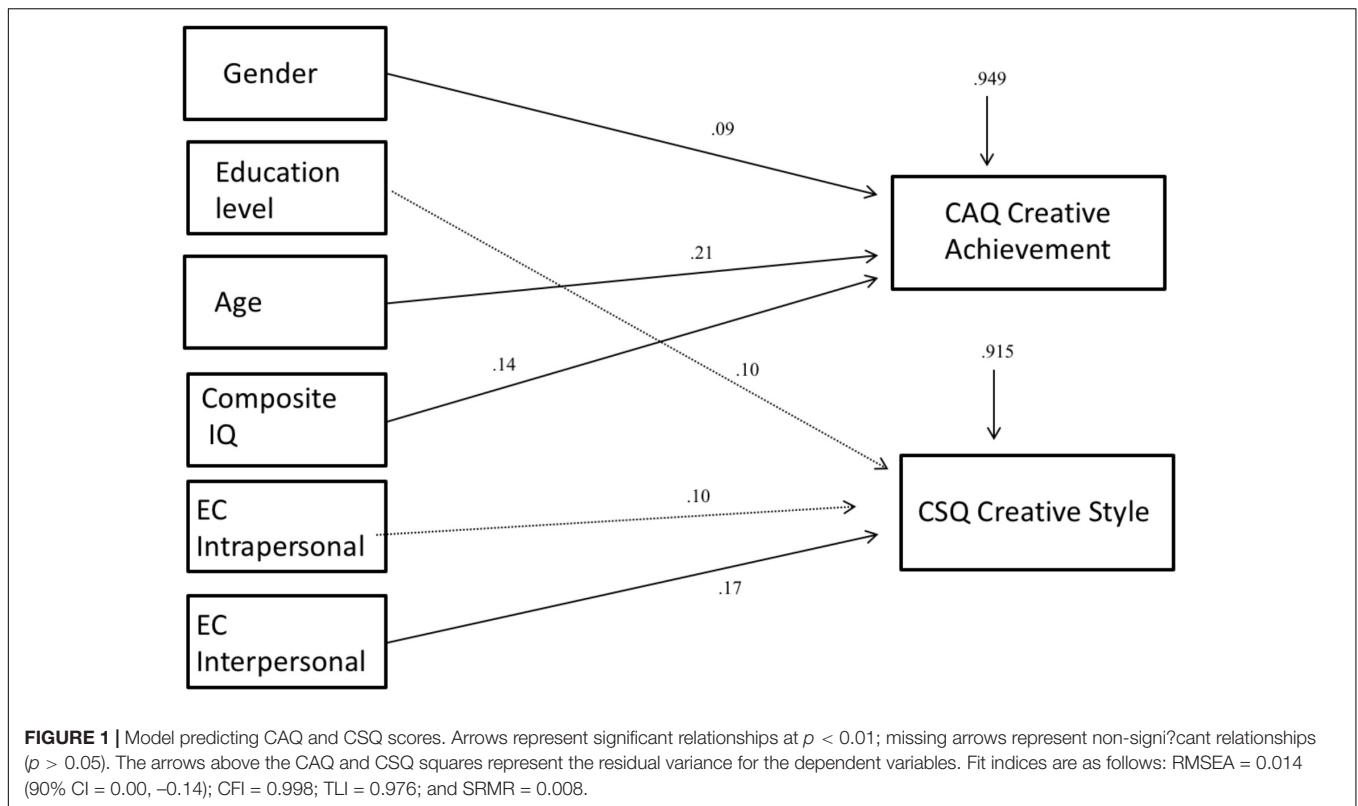
First, we explored correlational patterns amongst the considered variables. It emerged that IQ, as expected, was significantly related to educational level, but was not significantly related to EC, considering both intrapersonal and interpersonal domains. This reinforces the evidence that these two constructs are distinct from one another (Mayer et al., 1999). Furthermore, interpersonal and intrapersonal ECs were found to be significantly related, although the correlation index ( $r = 0.40$ ) reflects a medium effect size, suggesting that the two dimensions are not overlapped.

In order to evaluate predictors of creative achievements and creativity style a path analysis was applied.

Considering creative achievements, as measured by the CAQ questionnaire, path analysis showed that age, gender, and Composite IQ were significant predictors of creative achievement. Specifically, younger males, and people with high IQs were found to have higher achievements in creativity, that is, they reported to have reached higher outputs in different areas such as arts, sport, and so on. As far as creative style is concerned, as measured by CSQ-R, it emerged that interpersonal EC is a positive predictor of the measure, whereas IQ and gender did not prove to be significant predictors.

Based on previous literature, these results seem to confirm that gender is related to creative achievements but not to creativity styles (Simonton, 1994; Hardy and Gibson, 2015). In the present study this was also evidenced by the analysis on gender differences, where males were found to have higher achievement scores compared to females, but the two groups did not differ in any other variable considered, including creativity style. In other words, it seems that women have similar creative potential to males but differences emerge in the opportunity to transform this potential into concrete creativity output. Although only speculative, a possible interpretation of this finding might be in relation to the acknowledged gender gap within the labor market (Negrey and Rausch, 2009). This is in line with previous literature (e.g., Baer and Kaufman, 2008) that suggested a limited female accomplishment in creative achievements is possibly due to environmental and/or biological (Abra and Valentine-French, 1991) factors. Future research should extend these findings across different domains.

In the analysis of the role of demographic differences, age proved to be a significant predictor of creative achievements but not of creative style. These data are in line with previous evidence of a decrease in creative achievements in the elderly (Zhang and Niu, 2013), possibly associated with diminished interpersonal competence and cognitive resources, which might limit the opportunities for older people to translate their creative style into concrete creative outputs. Another account of this result regards dedifferentiation in old age (Baltes et al., 1999), which states that in the elderly creativity is mainly influenced by common sources. On the other hand, age did not significantly



predict creativity style and this suggests that action should be taken in order to facilitate the expression of creativity in the elderly.

Considering the role of EC, results from the present study suggest that particularly the interpersonal component, and marginally intrapersonal skills, represents a strong predictor of cognitive style but not of creative achievements. This is partially in line with studies that suggest that the openness trait is one of the most consistent personality predictors of creativity (e.g., Silvia et al., 2014; Conner and Silvia, 2015; Karwowski and Lebeda, 2015; Forthmann et al., 2018). In other words, over and above demographic differences in age, gender and education and taking into account cognitive skills connected to intellectual functioning, creative style can be predicted on the basis of people's skills in recognizing and managing one's own emotions and those of others. Thus, having good skills in understanding and managing others' emotions might represent a crucial skill for developing ideas and unconventional solutions. Considering a frequently used model to explain creativity called Knowledge, Skills, Abilities and Other Attributes (the so-called KSAO model), the present study might help in defining some aspects. With regards the "Other" category of the KSAO model, which typically includes personality traits, willingness to take risks (Schmitt and Chan, 1998; Motowidlo, 2003; Stevens, 2012), and motivation (Weitz et al., 1986), our results contribute to better specify the "Other" category by introducing age, gender, interpersonal EC, and Composite IQ. In other words, intelligence could be a necessary but-not-sufficient condition of creativity (e.g., Karwowski et al., 2017).

The design of the present study did not allow to directly test the threshold hypothesis (Guilford, 1981; Jauk et al., 2013) concerning the variation in creativity levels across different IQ levels, but our results suggest that IQ is principally related to creativity achievements and not to creativity style. In accordance with previous literature, the results from the present study suggest that IQ has differential effects on distinct domains of creativity (Jauk et al., 2013). In particular, better achievements seem to require higher IQ, possibly because the fulfillment of creative ideas into concrete outputs requires higher order cognitive skills that encompass the creativity domain.

The generalizability of the present study might be restricted by some limitations. First of all, the data on creativity styles and achievements were collected solely through behavioral questionnaires, so future investigations also including the evaluation of creative potential would be useful. Moreover, although the sample of the study was relatively large, it did not allow for detailed subgroup analysis based on individual differences variables. For example, further research involving a comparison of predictors across different age ranges would be valuable. A final consideration concerns cultural background: the present study was conducted on an Italian population and it would be intriguing to perform cross-cultural studies that considered trajectories for cultural mediated traits such as creativity. Despite these limitations, to the best of our knowledge this is the first study that puts together the analysis of demographic differences, intellectual functioning and EC as predictors of creativity style and achievements.

In summary, the results of the present study seem to be in line with some recent functional evidence, which fosters the idea that creativity arises from a complex interaction between cognitive skills, individual differences variables and EC. Furthermore, the study clearly highlighted a differential influence of cognitive, demographic, and emotional factors on the two distinct domains of creativity considered: achievements and cognitive style. This reinforces the idea that creativity is not an all-in-one construct. Possible implications from the present study could include the implementation of intervention programs that enhance not only the cognitive components associated with creative behavior but also EC and awareness.

## REFERENCES

- Abra, J. C., and Valentine-French, S. (1991). Gender differences in creative achievement: a survey of explanations. *Genet. Soc. Gen. Psychol. Monogr.* 117, 233–284.
- Abraham, A., Pieritz, K., Thybusch, K., Rutter, B., Kröger, S., Schweckendiek, J., et al. (2012). Creativity and the brain: uncovering the neural signature of conceptual expansion. *Neuropsychologia* 50, 1906–1917. doi: 10.1016/j.neuropsychologia.2012.04.015
- Adolphs, R. (2009). The social brain: neural basis of social knowledge. *Annu. Rev. Psychol.* 60, 693–716. doi: 10.1146/annurev.psych.60.110707.163514
- Alfonso, V. C., Flanagan, D. P., and Radwan, S. (2005). “The impact of the cattell–horn–carroll theory on test development and interpretation of cognitive and academic abilities,” in *Contemporary Intellectual Assessment, Second Edition: Theories, Tests, and Issues*, eds D. P. Flanagan and P. L. Harrison (New York, NY: Guilford Publications).
- Amabile, T. M. (1983). *The Social Psychology of Creativity*. New York, NY: Springer-Verlag. doi: 10.1007/978-1-4612-5533-8
- Anastasi, A. (1958). *Differential Psychology: Individual and Group Differences in Behavior*. Oxford: Macmillan.
- Andreasen, N. C. (1997). “Creativity and mental illness: prevalence rates in writers and their first-degree relatives,” in *Eminent Creativity, Everyday Creativity, and Health*, eds M. A. Runco and R. Richards (Greenwich, CT: Ablex), 7–18.
- Baddeley, A. D. (1968). A 3 min reasoning test based on grammatical transformation. *Psychon. Sci.* 10, 341–342. doi: 10.3758/BF0331551
- Baer, J. (1993). *Divergent Thinking and Creativity: A Task-specific Approach*. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.
- Baer, J., and Kaufman, J. C. (2008). Gender differences in creativity. *J. Creat. Behav.* 42, 75–105. doi: 10.1002/j.2162-6057.2008.tb01289.x
- Baltes, P. B., Staudinger, U. M., and Lindenberger, U. (1999). Lifespan psychology: theory and application to intellectual functioning. *Annu. Rev. Psychol.* 50, 471–507. doi: 10.1146/annurev.psych.50.1.471
- Batey, M., and Furnham, A. (2006). Creativity, intelligence and personality: a critical review of the scattered literature. *Genet. Soc. Gen. Psychol. Monogr.* 132, 355–429. doi: 10.3200/MONO.132.4.355-430
- Batey, M., Furnham, A., and Saffulina, X. (2010). Intelligence, general knowledge and personality as predictors of creativity. *Learn. Individ. Differ.* 20, 532–535. doi: 10.1177/0956797612450883
- Bland, J. M., Altman, D. G., and Rohlff, F. J. (2013). In defence of logarithmic transformations. *Stat. Med.* 32, 3766–3768. doi: 10.1002/sim.5772
- Blum, D., and Holling, H. (2017). Spearman’s law of diminishing returns, a meta-analysis. *Intelligence* 65, 60–66. doi: 10.1016/j.intell.2017.07.004
- Bonifacci, P., and Nori, R. (2016). *KBIT-2. Kaufman Brief Intelligence Test Second Edition. Contributo Alla Taratura Italiana [Contribution to Italian Standardization]*. Firenze: Giunti-OS.
- Cabello, R., Bravo, B. N., Latorre, J. M., and Fernández-Berrocal, P. (2014). Ability of university-level education to prevent age-related decline in emotional intelligence. *Front. Aging Neurosci.* 6:37. doi: 10.3389/fnagi.2014.00037
- Cabeza, R., McIntosh, A. R., Tulving, E., Nyberg, L., and Grady, C. L. (1997). Age-related differences in effective neural connectivity during encoding and recall. *Neuroreport* 8, 3479–3483. doi: 10.1097/00001756-199711100-00013

## AUTHOR CONTRIBUTIONS

RN, SS, and PB designed and conceived the study and discussed the results. SS collected data. SS analyzed the data. RN and PB wrote a first draft of the manuscript which has been further revised by all the authors.

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- Carlsson, I., Wendt, P. E., and Risberg, J. (2000). On the neurobiology of creativity. Differences in frontal activity between high and low creative subjects. *Neuropsychologia* 38, 873–885. doi: 10.1016/S0028-3932(99)00128-1
- Carson, S., Peterson, J. B., and Higgins, D. M. (2005). Reliability, validity, and factor structure of the creative achievement questionnaire. *Creat. Res. J.* 17, 37–50. doi: 10.1207/s15326934crj1701\_4
- Conner, T. S., and Silvia, P. J. (2015). Creative days: a daily diary study of emotion, personality, and everyday creativity. *Psychol. Aesthet. Creat. Arts* 9, 463–470. doi: 10.1037/aca0000022
- Craik, F. I., and Byrd, M. (1982). “Aging and cognitive deficits: the role of attentional resources,” in *Aging and Cognitive Processes*, eds F. I. M. Craik and S. E. Trehub (New York, NY: Plenum), 191–211.
- Deary, I. J., Penke, L., and Johnson, W. (2010). The neuroscience of human intelligence differences. *Nat. Rev. Neurosci.* 1, 201–211. doi: 10.1038/nrn2793
- Dietrich, A. (2004). The cognitive neuroscience of creativity. *Psychon. Bull. Rev.* 11, 1011–1026. doi: 10.3758/BF03196731
- Dudek, S. Z., and Verreault, R. (1989). The creative thinking and ego functioning of children. *Creat. Res. J.* 2, 64–86. doi: 10.1080/10400418909534301
- Dunbar, K. (1997). “How scientists think: On-line creativity and conceptual change in science,” in *Creative Thought: An Investigation of Conceptual Structures and Processes*, eds T. B. Ward, S. M. Smith, and J. Vaid (Washington, DC: American Psychological Association), 461–493.
- Feist, G. J. (1998). A meta-analysis of personality in scientific and artistic creativity. *Pers. Soc. Psychol. Rev.* 2, 290–309. doi: 10.1207/s15327957pspr0204\_5
- Finke, R. A., Ward, T. B., and Smith, S. M. (1992). *Creative Cognition: Theory, Research, and Applications*. Cambridge, MA: MIT press.
- Fjell, A. M., Westlye, L. T., Amlie, I., Espeseth, T., Reinvang, I., Raz, N., et al. (2009). High consistency of regional cortical thinning in aging across multiple samples. *Cereb. Cortex* 19, 2001–2012. doi: 10.1093/cercor/bhn232
- Forthmann, B., Regehr, S., Seidel, J., Holling, H., Çelik, P., Storme, M., et al. (2018). Revisiting the interactive effect of multicultural experience and openness to experience on divergent thinking. *Int. J. Intercult. Relat.* 63, 135–143. doi: 10.1016/j.ijintrel.2017.10.002
- Getzels, J. W., and Csikszentmihalyi, M. (1976). *The Creative Vision: A Longitudinal Study of Problem Finding in Art*. New York, NY: John Wiley & Sons.
- Guastello, S. J., Guastello, D. D., and Hanson, C. A. (2004). Creativity, mood disorders, and emotional intelligence. *J. Creat. Behav.* 38, 260–281. doi: 10.1002/j.2162-6057.2004.tb01244.x
- Guilford, J. P. (1967). *The Nature of Human Intelligence*. New York, NY: MacGraw-Hill.
- Guilford, J. P. (1981). Higher-order structure-of-intellect abilities. *Multivar. Behav. Res.* 16, 411–435. doi: 10.1207/s15327906mbr1604\_1
- Gunning-Dixon, F. M., Gur, R. C., Perkins, A. C., Schroeder, L., Turner, T., Turetsky, B. I., et al. (2003). Age-related differences in brain activation during emotional face processing. *Neurobiol. Aging* 24, 285–295. doi: 10.1016/S0197-4580(02)00099-4
- Hardy, J. H., and Gibson, C. (2015). Gender differences in the measurement of creative problem-solving. *J. Creat. Behav.* 51, 153–162. doi: 10.1002/jobc.92
- Hartung, J., Doebler, P., Schroeders, U., and Wilhelm, O. (2018). Dedifferentiation and differentiation of intelligence in adults across age and years of education. *Intelligence* 69, 37–49. doi: 10.1016/j.intell.2018.04.003



- Hildebrandt, A., Sommer, W., Schacht, A., and Wilhelm, O. (2015). Perceiving and remembering emotional facial expressions—A basic facet of emotional intelligence. *Intelligence* 50, 52–67. doi: 10.1016/j.intell.2015.02.003
- Houtz, J. C., Ponterotto, J. G., Burger, C., and Marino, C. (2010). Problem-solving style and multicultural personality dispositions: a study of construct validity. *Psychol. Rep.* 106, 927–938. doi: 10.2466/pr0.106.3.927-938
- Howitt, D., and Cramer, D. (2011). *Introduction to SPSS Statistics in Psychology: For Version 19 and Earlier*. Upper Saddle River, NJ: Prentice Hall.
- Hu, L. T., and Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Struct. Equ. Model.* 6, 1–55. doi: 10.1080/10705519909540118
- Hunt, E. (2010). *Human Intelligence*. Cambridge, MA: Cambridge University Press. doi: 10.1017/CBO9780511781308
- Hutt, C., and Bhavnani, R. (1976). “Predictions from play,” in *Plays Its Role in Development and Evolution*, eds J. S. Bruner, A. Jolly, and K. Sylva (New York, NY: Penguin), 216–219.
- Iidaka, T., Okada, T., Murata, T., Omori, M., Kosaka, H., Sadato, N., et al. (2002). Age-related differences in the medial temporal lobe responses to emotional faces as revealed by fMRI. *Hippocampus* 12, 352–362. doi: 10.1002/hipo.1113
- Ivcevic, Z., Brackett, M. A., and Mayer, J. D. (2007). Emotional intelligence and emotional creativity. *J. Pers.* 75, 199–235. doi: 10.1111/j.1467-6494.2007.00437.x
- Jankowska, D. M., and Karwowski, M. (2015). Measuring creative imagery abilities. *Front. Psychol.* 6:1591. doi: 10.3389/fpsyg.2015.01591
- Jauk, E., Benedek, M., Dunst, B., and Neubauer, A. C. (2013). The relationship between intelligence and creativity: new support for threshold hypothesis by means of empirical breakpoint detection. *Intelligence* 41, 212–221. doi: 10.1016/j.intell.2013.03.003
- Jung, R. E., Haier, R. J., Yeo, R. A., Rowland, L. M., Petropoulos, H., Levine, A. S., et al. (2005). Sex differences in N-acetylaspartate correlates of general intelligence: an 1H-MRS study of normal human brain. *Neuroimage* 26, 965–972. doi: 10.1016/j.neuroimage.2005.02.039
- Jung, R. E., Segall, J. M., Jeremy Bockholt, H., Flores, R. A., Smith, S. M., Chavez, R. S., et al. (2010). Neuroanatomy of creativity. *Hum. Brain Mapp.* 31, 398–409. doi: 10.1002/hbm.20874
- Karwowski, M., Dul, J., Gralowski, J., Jauk, E., Jankowska, D. M., Gajda, A., et al. (2016). Is creativity without intelligence possible? A necessary condition analysis. *Intelligence* 57, 105–117. doi: 10.1016/j.intell.2016.04.006
- Karwowski, M., Kaufman, J. C., Lebuda, I., Szumski, G., and Firkowska-Mankiewicz, A. (2017). Intelligence in childhood and creative achievements in middle-age: the necessary condition approach. *Intelligence* 64, 36–44. doi: 10.1016/j.intell.2017.07.001
- Karwowski, M., and Lebuda, I. (2015). The big five, the huge two, and creative self-beliefs: a meta-analysis. *Psychol. Aesthet. Creat. Arts* 10, 214–232. doi: 10.1037/aca0000035
- Kaufman, A. S., and Kaufman, N. L. (2005). *Kaufman Brief Intelligence Test*, 2nd Edn. Circle Pines, MN: American Guidance Service.
- Kaufman, J. C. (2015). Why creativity isn't in IQ tests, why it matters, and why it won't change anytime soon probably. *J. Intell.* 3, 59–72. doi: 10.3390/jintelligence3030059
- Kaufman, J. C. (2016). *Creativity 101*. New York, NY: Springer Publishing Company. doi: 10.1891/9780826129536
- Kaufman, J. C., and Beghetto, R. A. (2009). Beyond big and little: the four C model of creativity. *Rev. Gen. Psychol.* 13, 1–12. doi: 10.1037/a0013688
- Kaufman, J. C., Kaufman, S. B., and Lichtenberger, E. O. (2011). Finding creative potential on intelligence tests via divergent production. *Can. J. Sch. Psychol.* 26, 83–106. doi: 10.1177/0829573511406511
- Kaufman, J. C., and Plucker, J. A. (2011). “Intelligence and creativity,” in *Cambridge Handbooks in Psychology. The Cambridge Handbook of Intelligence*, eds R. J. Sternberg and S. B. Kaufman (New York, NY: Cambridge University Press), 771–783.
- Kaufman, S. B., Quilty, L. C., Grazioplene, R. G., Hirsh, J. B., Gray, J. R., Peterson, J. B., et al. (2016). Openness to experience and intellect differentially predict creative achievement in the arts and sciences. *J. Pers.* 84, 248–258. doi: 10.1111/jopy.12156
- Kumar, V. K., and Holman, E. R. (1989). *Creativity Styles Questionnaire*. West Chester, PA: Department of Psychology, West Chester University.
- Kumar, V. K., Kemmler, D., and Holman, R. (1997). The creativity styles questionnaire revised. *Creat. Res. J.* 10, 51–58. doi: 10.1207/s15326934crj1001\_6
- Kunzmann, U., Kupperbusch, C. S., and Levenson, R. W. (2005). Behavioral inhibition and amplification during emotional arousal: a comparison of two age groups. *Psychol. Aging* 20, 144–158. doi: 10.1037/0882-7974.20.1.144
- Manard, M., Carabin, D., Jaspar, M., and Collette, F. (2014). Age-related decline in cognitive control: the role of fluid intelligence and processing speed. *BMC Neurosci.* 15:7. doi: 10.1186/1471-2202-15-7
- Mathersul, D., Palmer, D. M., Gur, R. C., Gur, R. E., Cooper, N., and Gordon, E. (2008). Explicit identification and implicit recognition of facial emotions: II. Core domains and relationships with general cognition. *J. Clin. Exp. Neuropsychol.* 31, 278–291. doi: 10.1080/13803390802043619
- Mayer, J. D., Caruso, D. L., and Salovey, P. (1999). Emotional intelligence meets traditional standards for an intelligence. *Intelligence* 27, 267–298. doi: 10.1016/S0160-2896(99)00016-1
- Mayer, J. D., and Salovey, P. (1997). “What is emotional intelligence?,” in *Emotional Development and Emotional Intelligence: Implications for Educators*, eds P. Salovey and D. Sluyter (New York, NY: Basic Books), 3–31.
- Mayer, J. D., Salovey, P., and Caruso, D. R. (2002). *Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT) User Manual*. Toronto: MHS.
- McCann, C., Joseph, D. L., Newman, D. A., and Roberts, R. D. (2014). Emotional intelligence is a second-stratum factor of intelligence: evidence from hierarchical and bifactor models. *Emotion* 14, 358–374. doi: 10.1037/a0034755
- Mikolajczak, M., Brasseur, S., and Fantini-Hauwel, C. (2014). Measuring intrapersonal and interpersonal EQ: the Short Profile of Emotional Competence (S-PEC). *Pers. Individ. Differ.* 65, 42–46. doi: 10.1016/j.paid.2014.01.023
- Miller, L. J., Myers, A., Prinzi, L., and Mittenberg, W. (2009). Changes in intellectual functioning associated with normal aging. *Arch. Clin. Neuropsychol.* 24, 681–688. doi: 10.1093/arclin/acp072
- Motowidlo, S. (2003). “Job performance,” in *Handbook of Psychology, Vol. 12 Industrial and Organizational Psychology*, eds W. Borman, D. Ilgen, and R. Klimoski (Hoboken, NJ: John Wiley and Sons), 39–53.
- Muthén, L. K., and Muthén, B. O. (1998–2010). *Mplus User's Guide*, 6th Edn. Los Angeles, CA: Muthén & Muthén.
- Negrey, C., and Rausch, S. D. (2009). Creativity gaps and gender gaps: women, men and place in the United States. *Gen. Place Cult.* 16, 517–533. doi: 10.1080/09663690903148408
- Paguió, L. P., and Hollett, N. (1991). Temperament and creativity of preschoolers. *J. Soc. Behav. Pers.* 6, 975–982.
- Phillips, L. H., MacLean, R. D. J., and Allen, R. (2002). Age and the understanding of emotions: neuropsychological and sociocognitive perspectives. *J. Gerontol. B Psychol. Sci. Soc. Sci.* 57B, 526–530. doi: 10.1093/geronb/57.6.P526
- Piirto, J. (2004). *Understanding Creativity*. Scottsdale, AZ: Great Potential Press.
- Pinker, S., and Spelke, E. (2005). *The science of gender and science: Pinker vs. Spelke, A Debate. Presented at the Mind Brain and Behavior Initiative (MBB)*. Cambridge, MA: Harvard University.
- Plucker, J. A., Beghetto, R. A., and Dow, G. T. (2004). Why isn't creativity more important to educational psychologist? Potential, pitfalls and future directions in creativity research. *Educ. Psychol.* 39, 83–97. doi: 10.1207/s15326985ep3902\_1
- Raven, J. (2000). The Raven's progressive matrices: change and stability over culture and time. *Cogn. Psychol.* 41, 1–48. doi: 10.1006/cogp.1999.0735
- Rhodes, M. (1987). “An analysis of creativity,” in *Frontiers of Creativity Research: Beyond the Basics*, ed. S. G. Isaksen (Buffalo, NY: Bearly), 216–222.
- Richardson, A. G. (1986). Sex differences in creativity among a sample of Jamaican adolescents. *J. Creat. Behav.* 20:147. doi: 10.1002/j.2162-6057.1986.tb00433.x
- Ruffman, T., Henry, J. D., Livingstone, V., and Phillips, L. H. (2008). A meta-analytic review of emotion recognition and aging: implications for neuropsychological models of aging. *Neurosci. Biobehav. Rev.* 32, 863–881. doi: 10.1016/j.neubiorev.2008.01.001
- Runco, M. A. (1991). *Divergent Thinking*. New York, NY: Ablex Publishing.
- Runco, M. A. (1994). *Problem Finding, Problem Solving, and Creativity*. Westport, CT: Greenwood Publishing Group.
- Runco, M. A., and Acar, S. (2012). Divergent thinking as an indicator of creative potential. *Creat. Res. J.* 24, 66–75. doi: 10.1080/10400419.2012.652929
- Sánchez-Ruiz, M. J., Hernández-Torrano, D., Pérez-González, J. C., Batey, M., and Petrides, K. V. (2011). The relationship between trait emotional intelligence

- and creativity across subject domains. *Motiv. Emot.* 35, 461–473. doi: 10.1007/s11031-011-9227-8
- Sander, M. C., Lindenberger, U., and Werkle-Bergner, M. (2012). Lifespan age differences in working memory: a two-component framework. *Neurosci. Biobehav. Rev.* 36, 2007–2033. doi: 10.1016/j.neubiorev.2012.06.004
- Schmidt, C. P., and Sinor, J. (1986). An investigation of the relationships among music audiation, musical creativity, and cognitive style. *J. Res. Music Educ.* 34, 160–172. doi: 10.2307/3344746
- Schmitt, N., and Chan, D. (1998). *Personnel Selection: A Theoretical Approach*. Thousand Oaks, CA: SAGE Publications.
- Silvia, P. J., Beaty, R. E., and Nusbaum, E. C. (2013). Verbal fluency and creativity: general and specific contributions of broad retrieval ability (Gr) factors to divergent thinking. *Intelligence* 41, 328–340. doi: 10.1016/j.intell.2013.05.004
- Silvia, P. J., Beaty, R. E., Nusbaum, E. C., Eddington, K. M., Levin-Aspensson, H., and Kwapil, T. R. (2014). Everyday creativity in daily life: an experience-sampling study of “little c” creativity. *Psychol. Aesthet. Creat. Arts* 8, 183–188. doi: 10.1037/a0035722
- Simonton, D. K. (1994). *Greatness: Who Makes History and Why*. New York, NY: Guilford Press.
- Simonton, D. K. (2000). Creativity; cognitive, personal, developmental and social aspects. *Am. Psychol.* 55, 151–158. doi: 10.1037/0003-066X.55.1.151
- Smith, G. J. W., and Carlsson, I. (1983). Creativity in early and middle school years. *Int. J. Behav. Dev.* 6, 167–195. doi: 10.1177/016502548300600204
- Smith, G. J. W., and Carlsson, I. (1985). Creativity in middle and late school years. *Int. J. Behav. Dev.* 8, 329–343. doi: 10.1177/016502548500800307
- Smith, G. J. W., and van der Meer, G. (1994). “Generative sources of creative functioning,” in *Creativity and Affect*, eds M. P. Snow and M. A. Runco (Norwood, NJ: Ablex), 147–167.
- Sternberg, R. J., and Lubart, T. I. (1999). The concept of creativity: prospects and paradigms. *Handb. Creat.* 1, 3–15.
- Stevens, G. (2012). A critical review of the science and practice of competency modeling. *Hum. Resour. Dev. Rev.* 12, 86–107. doi: 10.1177/1534484312456690
- Tessitore, A., Hariri, A. R., Fera, F., Smith, W. G., Das, S., Weinberger, D. R., et al. (2005). Functional changes in the activity of brain regions underlying emotion processing in the elderly. *Psychiatry Res. Neuroimaging* 139, 9–18. doi: 10.1016/j.psychres.2005.02.009
- Torrance, E. P., Ball, O. E., and Safter, H. T. (1966). *Torrance Tests of Creative Thinking*. Bensenville, IL: Scholastic Testing Service.
- Trochim, W., and Donnelly, J. (2006). *The Research Knowledge Methods Base*. Cincinnati, OH: Atomic Dog Publishing.
- Tsai, J. L., Levenson, R. W., and Carstensen, L. L. (2000). Autonomic, subjective, and expressive responses to emotional films in older and younger Chinese Americans and European Americans. *Psychol. Aging* 15, 684–693. doi: 10.1037/0882-7974.15.4.684
- Ueno, K., Takahashi, T., Takahashi, K., Mizukami, K., Tanaka, Y., and Wada, Y. (2015). Neurophysiological basis of creativity in healthy elderly people: a multiscale entropy approach. *Clin. Neurophysiol.* 126, 524–531. doi: 10.1016/j.clinph.2014.06.032
- Unsworth, N., Spillers, G. J., and Brewer, G. A. (2010). Variation in verbal fluency: a latent variable analysis of clustering, switching, and overall performance. *Q. J. Exp. Psychol.* 64, 447–466. doi: 10.1080/17470218.2010.505292
- Urban, K. K., and Jellen, H. G. (1996). *Manual. Test for Creative Thinking-drawing Production*. Hanover: University of Hanover.
- Vartanian, O., Martindale, C., and Kwiatkowski, J. (2003). Creativity and inductive reasoning: the relationship between divergent thinking and performance on wason’s 2—4—6 task. *Q. J. Exp. Psychol. A* 56, 1–15. doi: 10.1080/02724980244000567
- Waddell, C. (1998). Creativity and mental illness: is there a link? *Can. J. Psychiatry* 43, 166–172.
- Weisberg, R. W. (2006). *Creativity: Understanding Innovation in Problem Solving, Science, Invention, and the Arts*. Hoboken, NJ: John Wiley & Sons.
- Weitz, B. A., Sujan, H., and Sujan, M. (1986). Knowledge, motivation, and adaptive behavior: a framework for improving selling effectiveness. *J. Mark.* 50, 174–191. doi: 10.2307/1251294
- Wilhelm, O., Herzmann, G., Kunina, O., Danthiir, V., Schacht, A., and Sommer, W. (2010). Individual differences in perceiving and recognizing faces—One element of social cognition. *J. Pers. Soc. Psychol.* 99, 530. doi: 10.1037/a0019972
- Wisdom, N. M., Mignogna, J., and Collins, R. L. (2012). Variability in wechsler adult intelligence scale-IV subtest performance across age. *Arch. Clin. Neuropsychol.* 27, 389–397. doi: 10.1093/arclin/acs041
- Wu, C. H., Cheng, Y., Ip, H. M., and McBride-Chang, C. (2005). Age differences in creativity: task structure and knowledge base. *Creat. Res. J.* 17, 321–326. doi: 10.1207/s15326934crj1704\_3
- Zhang, W., and Niu, W. (2013). Creativity in the later life: factors associated with the creativity of the Chinese elderly. *J. Creat. Behav.* 47, 60–76. doi: 10.1002/jocb.23

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# High Schizotypal Individuals Are More Creative? The Mediation Roles of Overinclusive Thinking and Cognitive Inhibition

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Although a theoretical link between positive schizotypy and heightened creativity has been established in the literature, little empirical research has been conducted to examine the underlying cognitive processes that contribute to this association. In addition, previous studies found a negative relationship between positive schizotypy and cognitive inhibition; however, they often used the paradigm of latent inhibition. This study used the paradigm of prepotent response inhibition indicated by Stroop interference effect and examined the mediation effects of overinclusive thinking (OT) and cognitive inhibition on the creativity of schizotypal individuals. Two groups of low and high schizotypal individuals ( $N = 78$ ) participated in the study. Each participant completed one OT task, one color-word Stroop task, three other executive functioning (EF) control tasks, and two creativity tasks. The results indicated that the high schizotypal group outperformed the low schizotypal group in the creativity tasks. They also exhibited higher OT as indicated by faster reaction time and higher cognitive inhibition as indicated by lower Stroop interference effect. Further, participant's levels of OT and cognitive inhibition partially mediated the relationship between schizotypy and creativity. The results were discussed under the context of schizotypy and creativity research and implications for rehabilitation were further provided.

**Keywords:** creativity, cognitive inhibition, intelligence, overinclusive thinking, schizotypy, shifting, working memory

## INTRODUCTION

The relationship between psychopathology and creativity has been a topic of interest for researchers over the last five decades (Karlsson, 1970; Hasenfeld and Magaro, 1976). Researchers have consistently suggested that, overall, there is a statistically significant correlation between the two variables; however, the direction and strength of the relationship depends on many factors, such as the specific symptoms of psychopathology, measures of creativity, and types of creativity (Jones et al., 2011; Fink et al., 2014a; Paek et al., 2016; Taylor, 2017). For instance, some researchers have indicated a negative relationship between the two variables, that is, less severe symptoms of psychopathology are significantly correlated with higher level of creativity (Claridge and Blakey, 2009; Barrantes-Vidal, 2014; Fink et al., 2014a). Although other

researchers agree with this notion, they further noted that the two variables has an inverted-U relationship, that is, the mild expressions of psychopathology may facilitate creativity but its full symptoms may hinder it (Acar et al., 2018). Some researchers have demonstrated that people who are prone to psychosis characterized by delusion, hallucination, and negative symptoms show more creativity (Heckers et al., 2013; Fink et al., 2014a). In a recent meta-analysis of 32 studies, researchers have found that the overall mean effect size of the association between creativity and psychoticism is small but the large effect size only shows when psychoticism is measured by the Eysenck Personality Questionnaire and uniqueness is an indicator of creativity (Acar and Runco, 2012). In addition, researchers showed that the negative relationship between schizophrenia and creativity becomes stronger among patients of chronic schizophrenia (Jaracz et al., 2012; Acar et al., 2018) and when creativity is measured by semantic or verbal-letter fluency tasks (Acar et al., 2018). Further, previous studies have revealed that those having schizophrenia, bipolar disorder, or unipolar depression and their relatives were overrepresented in creative occupations and that those with schizophrenia show more artistic and writing creativity (Kyaga et al., 2011, 2013; Rybakowski and Klonowska, 2011).

Similar to the notion that the relationship between psychopathology and creativity depends on the symptoms and severity of psychopathology, researchers have indicated that, rather than schizophrenia, it is schizotypy<sup>1</sup>, a personality trait similar to schizophrenia symptoms but at a diminished level (Debbane and Mohr, 2015), that explains general creativity<sup>2</sup> and creative performance (Kaufman and Paul, 2014; Fisher, 2015; Wang et al., 2017). While schizophrenia is a psychiatric disorder, schizotypy is a psychological construct that is characterized by the personality traits, such as magical ideation (the propensity to have non-conventional beliefs and accept causality not culturally valid), perceptual aberration (the distorted perception of body and objects), anhedonia, social withdrawal, eccentric behavior, and odd speech (Schulberg et al., 1988; Cox and Leon, 1999; Nelson et al., 2013). Among these characteristics of schizotypy, magical ideation and perceptual aberration are viewed as positive schizotypy, whereas anhedonia and social withdrawal are viewed as negative schizotypy (Chen et al., 1997; Cox and Leon, 1999; Grimshaw et al., 2010; Rominger et al., 2013). This categorization is consistent with the previous findings that proneness to approach-based psychopathologies (e.g., positive schizotypy and risk of bipolar disorder) are positively related with creativity, whereas proneness to avoidance-based psychopathologies (e.g., anxiety, negative schizotypy, and depressive mood) are negatively related with creativity (Baas et al., 2016).

A substantial amount of studies has shown that individuals with higher levels of schizotypal personality traits attain higher creative achievement and creative performance in assessment

tasks. For instance, in one study, visual artists were reported to score significantly higher than the non-artists in all the measures of schizotypy and divergent thinking tasks (Burch et al., 2006). In another study, positive correlations were found in the following relationships: self-rated creativity and unusual experience aspect of schizotypy measured by the Oxford-Liverpool Inventory of Feelings and Experiences (O-LIFE: Mason et al., 1995); creative personality measured by Creative Personality Scale (Gough, 1979), creative achievement measured by Biographical Inventory of Creative Behaviors (BICB, Batey, 2007) and impulsive non-conformity of schizotypy; the total creativity aggregated by the three measures (self-rated, CPS, and BICB) and unusual experiences and impulsive non-conformity (Beaty and Furnham, 2008). A more recent study also found that high schizotypal individuals showed significant advantages over low schizotypal individuals in both verbal (Alternative Uses Test) and figural (Figure Completion and Extraterrestrial Drawing) DT tasks (Wang et al., 2017).

Although the relationship between schizotypal traits and creative performance seems to be well-established, little research has directly explored the cognitive underpinnings of the relationship (Crabtree and Green, 2016). One study examined the common factors that predispose an individual to both creativity and psychosis and indicated that overinclusive thinking (OT) and cognitive inhibition may function as the cognitive link between schizotypy and creativity (Acar and Sen, 2013). This is in line with the underlying cognitive process of the dual process model that has been discussed in the field of creativity. That is, engaging in creative tasks may involve both automatic or associative process and effortful or controlled process (Schmajuk et al., 2009; Beaty et al., 2014, 2016; Edl et al., 2014; Forthmann et al., 2016). However, to date, very few studies have examined the effects, particularly mediation effects, of OT and cognitive inhibition, on the relationship of schizotypy and creativity. The current study attempts to fill this gap in the literature.

## LITERATURE REVIEW

### Overinclusive Thinking, Schizotypy, and Creativity

Overinclusive thinking is usually conceptualized as the inability to preserve conceptual boundaries and identified as a cognitive characteristic of individuals with schizotypy who show an over-responsiveness to associative or irrelevant aspects of words and extraneous stimuli (Payne and Friedlander, 1962). People with OT tend to have a broader conceptual boundary. For example, when answering the questions in categorization tasks, such as “Are feet vehicles?”, people with OT tend to think of feet as vehicles based on the fact that feet transport people and items from one place to another just like vehicles. However, people without OT would not place feet in the vehicle category because they believe that wheels are the necessary features of vehicles (Chiu, 2015). Prior research has also recognized loose associative processing, or allusive thinking, as a feature of the cognitive processes of individuals with schizophrenia spectrum (Meehl, 1990). An empirical study that evaluated predisposing

<sup>1</sup>Schizotypy refers more specifically to positive schizotypy in the paper unless it is indicated otherwise.

<sup>2</sup>Creativity in this paper mainly refers to everyday creativity (please see Kaufman and Beghetto, 2009 for the more details).

factors related to cognitive control further revealed that common components of positive schizotypy may underlie the disposition to perceive meaningful coincidences and to engage in loose associative processing (Rominger et al., 2011). Another study focusing on the neuropsychological functioning of individuals with schizotypal traits also indicated that, when compared to the healthy control group, high schizotypal individuals demonstrated decreased ability in conceptualization (Kim et al., 2011).

Past research on the nature of creativity has further suggested that the schizotypal trait of OT may play a fundamental role in creative cognition (Eysenck, 1993; Mohr et al., 2001). For instance, the dual process theory of creative cognition indicates that both associative and executive processes are involved to produce novel ideas (Mednick, 1962; Benedek et al., 2012b; Beaty et al., 2014; Forthmann et al., 2016). A study relating creativity to personality proposed that OT may play a leading role in creativity during mental searching processes by providing individuals with more ideas and increasing the possibility of producing creative ideas (Eysenck, 1993; Mohr et al., 2001). Another study examining the relationship between divergent thinking and OT showed that scores on OT measured by Lovibond's Object Sorting Test were positively correlated with originality of divergent thinking tasks, which were a reliable measure of creativity (Rawlings and Toogood, 1997). Similar to previous research, the present study employed categorization task to assess OT in terms of typicality rating and Reaction Time (RT) for the untypical exemplars. We developed the following two hypotheses on the relationships among OT, schizotypy, and creativity:

- (1a) The high schizotypy group has significantly higher OT than the low schizotypy group, as indicated by higher rating and/or greater RT for untypical exemplars;
- (1b) There is a positive correlation between OT and creativity measured by Alternative Uses Test and an extraterrestrials drawing task.

## Cognitive Inhibition, Schizotypy, and Creativity

Cognitive inhibitory control ability is a family of functions with three potentially separable processes—pre-potent response inhibition (PRI), resistance to distractor interference and resistance to proactive interference (Friedman and Miyake, 2004). Past studies have consistently reported a positive relationship between schizotypy and creativity but a negative relationship between schizotypy and cognitive inhibition (Beech et al., 1989; Moritz and Mass, 1997; Green and Williams, 1999; Kaplan and Lubow, 2011). Reduced cognitive inhibition was further hypothesized to link creativity to schizotypy (Eysenck, 1993; Acar and Sen, 2013; Fink et al., 2014b). However, the role of cognitive inhibition in the association between schizotypy and creativity has not yet been confirmed (Green and Williams, 1999; Crabtree and Green, 2016). This lack of the effect of cognitive inhibition on the creativity of schizotypal individuals may be because the positive association between the two variables has often been explained by reduced latent inhibition (LI), which refers to the phenomenon of neglecting

target in test stage by rendering it as a distractor in the pre-exposure stage and represents the difficulty of processing a target that was previously irrelevant. It is reflected in the longer RT to pre-exposed target than to non-pre-exposed target. For example, ♡ serves as a distractor in pre-exposure stage and transforms to a target in the test stage, then RT to ♡ is slower than to novel target ♣ (Lubow et al., 2000).

However, some researchers have argued that the association between schizotypy and creativity may be more related to PRI indicated by Stroop interference effect because it is the active inhibition of pre-potent response (Friedman and Miyake, 2004), whereas LI, as the automatic resistance to proactive interference, does not give rise to awareness (Höfer et al., 1999). Stroop interference effect is indicated by slower RT to a task-incongruent stimulus (word: red; font color: green; task: name font color) than to a task-congruent stimulus (word: green; font color: green; task: name font color) (Edl et al., 2014). For this reason, PRI measured by Stroop interference effect was employed as the paradigm in the current study to conceptualize cognitive inhibition. Given schizotypy was related with reduced Stroop interference effect (Green and Williams, 1999) and Stroop interference effect was positively related with LI (Kaplan and Lubow, 2011), high level of cognitive inhibition is shown in reduced Stroop interference effect rather than lower level of LI in the current study.

Although some studies reported that inhibitory control hinders creative performance (Benedek et al., 2012a, 2014; Radel et al., 2015), other studies suggested that engaging in creative problem solving process requires the inhibition of past inappropriate ideas inducing fixation phenomena (Cassotti et al., 2016). Several studies have also revealed a positive association between reduced Stroop interference effect and creativity. For instance, reduced Stroop interference effect was positively correlated with enhanced verbal originality and fluency measured by the Torrance Test of Creative Thinking (Edl et al., 2014). The Stroop interference effect, which was considered a reversed indicator of inhibition, was also found to positively predict creative performance measured by divergent thinking tasks in a latent variable modeling study (Benedek et al., 2014). These findings imply that cognitive inhibition might suppress the interference of prominent ideas during the process of creating original ideas or products (Benedek et al., 2014). Based on the literature review, we made the following two hypotheses:

- (2a) The high schizotypy group has higher cognitive inhibition than the lower schizotypy group, as indicated by reduced Stroop interference effect;
- (2b) There is a positive correlation between cognitive inhibition measured by reduced Stroop interference effect and creativity.

Furthermore, according to the two sets of hypotheses mentioned earlier, we also hypothesized that OT and cognitive inhibition mediate the relationship between schizotypy and creativity.

## MATERIALS AND METHODS

### Participants

Participants were selected from a subject pool consisting of 388 students from two colleges in Shanghai, China by using the Chinese version of Schizotypal Personality Questionnaire (SPQ) (Raine, 1991; Chen et al., 1997). Those who had personal history of mental disorders, neurological disorders, head trauma, and drug abuse and dependence were excluded from the study. Following several previous researchers (Meehl, 1990; Abraham and Windmann, 2008; Bedwell et al., 2011; Fink et al., 2014b; Chan et al., 2016; Koychev et al., 2016), we used categorical sampling approach and selected the high and low schizotypy participants based on the 10% base rate of schizotypy in the general population. More specifically, participants whose total scores on the SPQ fell into top tenth percentile were recruited as high schizotypy group and participants whose total scores on the SPQ fell into lowest tenth percentile were recruited as low schizotypy group (see **Table 1** for descriptive statistics of total SPQ and three SPQ factors in high schizotypy and low schizotypy groups). It may be more likely to detect the effect of schizotypy on creativity by using categorical sampling approach because “the maximum schizotypy effect would be achieved using a design that compares low and high schizotypes” (Koychev et al., 2016, p. 1). A global score of schizotypy was employed, following previous studies on schizophrenia that used the same practice (Abraham et al., 2007; Jones et al., 2011; Oertel-Knochel et al., 2013; Lui et al., 2016; Wang et al., 2017).

In the final sample, there were 37 participants in the high schizotypy group, with 34 being female and 3 being male. The mean age of this group was 21.54 ( $SD = 1.33$ ) and the mean education year was 14.14 ( $SD = 1.38$ ). There were 41 participants in the low schizotypy group, with 35 being female and 6 being male. The mean age of this group was 21.73 ( $SD = 1.45$ ) and the mean education year was 14.12 ( $SD = 1.36$ ). There were no significant differences between two groups in terms of age [ $t_{(76)} = 0.61, p = 0.55$ ], gender [ $X^2_{(1)} = 0.26, p = 0.61$ ], and years of education [ $t_{(76)} = 0.05, p = 0.96$ ]. In addition, participants all reported normal color vision and normal or corrected-to-normal acuity before testing without taking drug or coffee. These participants formed a homogeneous sample because they had similar age, education background, and major, which minimizes the individual differences that are independent of schizotypy.

### Measures

#### Schizotypal Personality Questionnaire

The 74-item SPQ is one of the schizotypy self-report questionnaires that have been most extensively used in the field (Abraham and Windmann, 2008). This questionnaire was originally developed based on the criteria for schizotypal personality disorders that were specified in the Diagnosis and Statistical Manual of Mental Disorder (Revised 3rd Edition, DSM-III-R, Raine, 1991). It uses binary true/false format and assesses all the nine schizotypal traits that are contained in cognitive-perceptual (called as positive schizotypy), interpersonal (called as negative schizotypy), and disorganization

factors. Some example items are “Do you ever suddenly feel distracted by distant sounds that you are not normally aware of?”, “Are your thoughts sometimes so strong that you can almost hear them?”. It was adapted by Chinese researchers (Chen et al., 1997) and has been used in Chinese context over the past two decades with good reliability and validity evidence. The reliability of the questionnaire in the current study was high (Cronbach's  $\alpha = 0.92$ ).

#### Cognitive Inhibition

As mentioned earlier, PRI indicated by reduced Stroop Inference effect was used in the study as the paradigm of cognitive inhibition. The Stroop task was adapted from Bailey et al.'s (2010) study. Congruent [e.g., Chinese character for “red” (红) in red] and incongruent [e.g., Chinese character for “red” (红) in green] color-words or strings of four Xs in colors red, blue, green or yellow were presented as stimuli at the center of the computer screen on a black background. The implementation of the Stroop task included three phases: key-mapping, practice, and test phase. The key-mapping phase included 40 trials with strings of four Xs as stimuli (10 trials for each color). During this phase, participants were instructed to verify the color of the stimulus as quickly and correctly as possible by pressing the key mapped to the color of the stimuli. The practice phase consisted of 12 congruent and 12 incongruent trials with color-words as stimuli. The test phase consisted of four blocks of 72 trials with color-words as stimuli. Each block included 36 congruent and 36 incongruent stimuli. The congruent and incongruent stimuli were pseudo-randomized in both practice and test phrases. When the participants gave press response, a trial was terminated. Incorrect response was given a feedback for 1000 millisecond (ms) and correct response was followed by a blank screen of 500 ms to ensure a high degree of Accuracy (ACC). The response, response time (RT), and ACC were recorded<sup>3</sup>. The test-retest reliability coefficients of the color-word Stroop were adequate: RT (0.86), interference effect (0.68).

#### Executive Functioning

Participants' executive functioning (EF) was considered control variable in the study and included working memory capacity, shifting ability, and reasoning ability.

#### Working memory capacity

Working memory capacity was assessed by an operation span task that was adapted from Lin and Lien (2013). In this task, a set of equation-word pairs was presented on computer screen one by one. Participants were required to verify a simple math equation [e.g.,  $(9/3) + 3 = 6$ ] by pressing button (“1” for correct, “0” for wrong) while memorizing a two-character Chinese word [e.g., “信息” (Information)]. Each equation-word pair remained on screen either until a verification response was given or for a maximum of 5 s. In order to ensure a high ACC, a feedback for 1 s was given after each response. At the end

<sup>3</sup>The false responses were not removed in this study. However, we analyzed the data removing the false responses based on the criterion of 3 standard deviations above/below the mean and the results remains the same as those not removing the false responses.

**TABLE 1** | Descriptive statistics of SPQ in the low and high schizotypy groups.

	SPQ total		SPQ Cognitive-Perceptual		SPQ Interpersonal		SPQ Disorganization	
	Mean (SD)	Minimum (Maximum)	Mean (SD)	Minimum (Maximum)	Mean (SD)	Minimum (Maximum)	Mean (SD)	Minimum (Maximum)
Low schizotypy	6.22 (2.42)	0 (9)	3.22 (1.88)	0 (8)	2.10 (1.73)	0 (7)	1.27 (1.16)	0 (6)
High schizotypy	44.95 (6.25)	38 (69)	20.35 (3.77)	10 (29)	18.46 (4.64)	8 (31)	10.38 (3.42)	5 (18)

of each trial, participants were instructed to write down all the words presented in the whole trial on the computer. For instance, if there were four equation-word pairs in a trial, the participants would verify the equation and memorize the word from each pair concurrently and then write down the four words at the end of the trial. After practicing on three trials at a set size of 3 (i.e., three equation-word pairs), participants acted upon experimental trials at a set size from 2 to 7. There were three trials at each set size. If the participants could not accurately recall all the words for more than two trials at any given set size when correct equation verification was required, the test would stop. The highest set size accomplished by participants indicated the level of working memory capacity. The test-retest reliability for the operation span task was adequate ( $r = 0.77$ ).

### Shifting ability

Shifting ability in EF was assessed by number-letter task that was adapted from Miyake et al. (2000). A number-letter pair (e.g., 3E) was displayed in one of four quadrants on computer screen. The participants were required to judge whether the number in the pair was odd or even (3, 5, 6, and 9 for odd; 2, 4, 6, and 8 for even) when the pair was displayed in left or right upper quadrant. They were also required to judge whether the letter in the pair was a consonant or vowel (A, E, I, and U for vowel; G, K, M, and R for consonant) when the pair was displayed in left or right lower quadrant. The number-letter pair was displayed only in the two upper quadrants for the first block of 32 trials, only in the two lower quadrants for the second block of 32 trials, and in a clockwise rotation around all four quadrants for the third block of 128 trials. Ten practice trials were employed in the first and second blocks and 12 practice trials were used in the third block. Thus, the trials within the first and second blocks required no mental shifting, while half of the trials in the third block required the participants to shift between two types of operation (“number” or “letter”). The participants responded by pressing button “D” for “odd,” “F” for “even,” “J” for “vowel,” and “K” for “consonant.” To enhance ACC, there was a fixation for 500 ms before each response and a feedback for 800 ms after each response. The shifting ability was scored by the difference between the average RT of the trials in the third block that required a mental shift (trials from the upper left and lower right quadrants) and the average RT of the trials from the first two blocks that required no shift. The smaller the difference is, the better the shifting ability. The internal reliability estimate for the number-letter task was excellent ( $r = 0.91$ ).

### Reasoning ability

Reasoning ability was measured by Raven Advanced Progressive Matrices (RAPM), a non-verbal intelligence test. Only 18 out of 36 items were employed in the study, which were all the odd items in the test (Nusbaum and Silvia, 2011). All the items were presented in black ink on white background and ordered by the level of difficulty, with the easiest item being placed at first and the most difficult item being placed at last. The participants were required to identify the missing element to complete a pattern. They worked on 18 reasoning items for 12 min. The number of correctly answered items was the final score of each participant. The internal reliability estimate for RAPM was good ( $r = 0.87$ ).

### Overinclusive Thinking

Overinclusive thinking was assessed by a categorization task that was adapted from Chiu (2015). Typical and untypical exemplars of clothing category and vehicle category were used as stimuli in the task. Three typical and three untypical exemplars were included in each category. The clothing category included typical exemplars (i.e., suit, shirt, and pants) and untypical exemplars (i.e., ring, purse, and cane). The vehicle category also included typical exemplars (i.e., train, automobile, and bus) and untypical exemplars (i.e., camel, feet, and elevator). Each exemplar was presented on the computer screen consecutively until the participants gave a response. The participants were required to rate the typicality of exemplars on a 10-point Likert scale by pressing the corresponding number key, in which 0 indicated “definitely does not belong to the clothing (or vehicle) category” and 9 indicated “definitely belongs to the clothing (or vehicle) category.” The typicality rating and RT for each exemplar were recorded. The level of OT was indicated by the average score of typicality rating and RT for untypical exemplars of clothing and vehicle category (Chiu, 2015). Individuals with high OT were expected to have higher typicality rating or faster RT for untypical exemplars.

### Creativity

Creativity was measured by multiple approaches because previous research showed that multiple ways of measuring creativity yield better results (Long, 2014a). First, participants’ verbal divergent thinking was assessed by Alternate Uses Test (AUT), a widely employed divergent thinking task (Beatty et al., 2014; Hao et al., 2014b). Although divergent thinking ability is not synonymous to creativity, divergent thinking tasks have been long employed to measure the originality and fluency of ideation (Runco, 1991; Long, 2014a; originality is preferred as an indicator of creativity because it has a conceptual relationship

with standard definition of creativity, Forthmann et al., 2017). Participants were required to write down as many original uses as possible for four everyday objects (i.e., tire, barrel, pencil, and brick) within 3 min for each task. The creativity of the ideas generated from the AUT tasks were measured by originality and fluency (Guilford, 1967). Originality scores were assessed with subjective scoring method based on the Consensual Assessment Technique (CAT) (Amabile, 1982) because individuals usually have various interpretations for originality and how to score it is somewhat subjective (Long, 2014b). Each response was rated on a 5-point scale (1 = "Not original at all" 5 = "Highly original") (Hao et al., 2014a) by six trained raters. The final originality score of each response was the mean of the six ratings. The originality of each task was the mean of the total originality scores of all the responses. The interrater reliability of the originality scores in the AUT tasks was satisfactory (Cronbach's  $\alpha = 0.70$ ). Fluency scores were indicated by the total number of responses given by the participants for each AUT task. The originality and fluency scores of the four AUT tasks were averaged for every participant. The inter-rater reliability for AUT tasks were excellent ( $r = 0.88$ ).

Participants' creativity was also measured by extraterrestrial task that was developed by Ward (1994) aiming to tap the ability of breaking the boundaries of established concepts to create original products. Participants were given 20 min to draw imagined extraterrestrial creatures from front and side, respectively, and to briefly describe the drawings. They were told in the instruction that the extraterrestrial animals living on another planet were supposed to be different from the creatures on the Earth, so they can draw the creature as original as possible. Participants were also asked to report whether they had previous training on drawing and no significant difference was found between the two groups [ $t_{(76)} = 0.14, p = 0.89$ ].

Participants' drawings were assessed by two aspects: difference and originality. The difference score reflected the number of major differences between the extraterrestrial creatures drawn by participants and typical Earth creatures. The coding procedures of difference were in accordance with the approach of previous studies (Ward et al., 2004; Abraham and Windmann, 2008). Two coders assessed the difference by coding the presence or absence of five attributes in the drawings: bilateral symmetry, typical appendages (leg, arm, wing, and tail), typical sense organs (eye, mouth, nose, and ear), unusual appendages, and unusual sense organs. The presence or absence of any of the former three attributes was given a score of 0 or 1, and the presence or absence of either of the latter two attributes was given a score of 1 or 0. More specifically, the use of bilateral symmetry, one or more of the four typical appendages, and one or more of the four typical sense organs, was scored 0. For instance, an appendage was considered unusual and scored 1 if it contained atypical number (e.g., three legs), had extraordinary function (e.g., respiration with leg), or non-existent for Earth creatures (e.g., wheels). A sense organ was considered unusual and scored 1 if it contained atypical number (e.g., one eye), had fantastical function (e.g., sensing temperature up to 5 kilometers away), non-existent for Earth animals (e.g., built-in memory bank), or had odd

arrangement of the sense organs (e.g., nose on the belly). The final difference score of the drawings ranged from 0 to 5. The final rating score was used when both coders were in agreement. When the two raters were not in agreement (less than 2% of all observations in the study), a third coder was consulted and the majority of the rating was used.

Originality score of the drawing was rated on a 7-point scale (Ward et al., 2004; Hao, 2010) (1 = "Not at all original" 7 = "Highly original") by five trained raters based on the Consensual Assessment Technique (CAT) (Amabile, 1982). The originality scores provided by five raters were averaged for every participant. The interrater reliability of the originality scores was satisfactory (Cronbach's  $\alpha = 0.84$ ).

## Procedure

This study was approved by the IRB of the university where the study was conducted. Written informed consents were obtained from participants prior to the study. A few weeks before the study, potential participants completed SPQ and the final sample of the participants were selected based on the results of SPQ. All the selected participants took part in the study in a group of 5–10 individuals in a quiet classroom. They were instructed to work on the Stroop task, Operation Span task, Number-letter task, Categorization task, Alternative uses test (AUT), Extraterrestrial animal task, and RAPM consecutively. This order was employed to minimize the effects of fatigue on RT and ACC in the first three tasks. The Stroop task, Operation Span task, Number-Letter task, and Categorization task were programmed in E-Prime software on computer. The response, RT and ACC were directly recorded in the computer. All of the other tasks were completed by using paper-and-pencil tests. The whole process lasted for 90 min. After the completion of the study, the participants were debriefed and rewarded 40 RMB (or about 6 dollars) as compensation. In order to be consistent, the protocol for the two groups was identical, and the administrations of the creativity assessment were performed by the same researchers.

## Data Analysis

All the statistical analyses were performed in IBM SPSS Version 24. Independent sample *t*-test and analyses of variance (ANOVA) were used to compare group differences in creativity indices, OT, and executive function tasks. Pearson correlation coefficients were used to examine the correlation between creativity indices and performance on OT and executive function tasks in the entire sample. Two mediation analyses were run for the effect of OT and cognitive inhibition on the relationship between schizotypy and creativity. The approaches to establish mediation suggested by Hayes (2009), including regression and bootstrapping, were used.

## RESULTS

Means and standard deviations (SDs) of creativity tasks, OT task, cognitive inhibition, and other executive function tasks are presented in **Table 2**.



**TABLE 2** | Descriptive statistics of creativity, overinclusive thinking, cognitive inhibition, and executive functioning tasks in the low and high schizotypy groups.

Task	Low schizotypy <i>n</i> = 41 <i>M</i> ( <i>SD</i> )	High schizotypy <i>n</i> = 37 <i>M</i> ( <i>SD</i> )	<i>t</i> <sub>(76)</sub>	<i>p</i>
AUT originality	2.43 (0.26)	2.55 (0.26)	-2.01	0.048
AUT fluency	5.84 (2.67)	7.07 (3.04)	-1.90	0.062
Extraterrestrials difference	1.32 (0.97)	2.00 (1.08)	-2.92	0.005
Extraterrestrials originality	4.02 (1.15)	4.64 (1.05)	-2.46	0.016
Categorization RT: typical	2.31 s (1.01)	2.36 s (1.17)	-0.18	0.858
Categorization RT: untypical	3.58 s (1.81)	2.79 s (1.19)	2.26	0.027
Categorization Rating: typical	8.85 (0.35)	8.76 (0.40)	0.99	0.327
Categorization Rating: untypical	3.51 (1.83)	3.80 (1.90)	-0.67	0.503
Stroop RT: congruent	876.07 ms (220.25)	830.50 ms (237.91)	0.88	0.382
Stroop RT: incongruent	1034.6 ms (289.71)	934.01 ms (236.62)	1.67	0.099
Stroop interference effect	158.53 ms (92.17)	103.52 ms (61.64)	3.06	0.003
Stroop ACC	0.95 (0.04)	0.96 (0.02)	-2.31	0.024
Number-letter RT	491.15 ms (298.77)	419.51 ms (267.12)	1.14	0.257
Number-letter ACC	0.96 (0.04)	0.96 (0.04)	-0.34	0.732
Operation span	4.00 (0.78)	3.81 (0.94)	0.98	0.333
RAPM	10.78 (2.62)	11.30 (2.57)	-0.88	0.383

AUT, Alternative Uses Test; RT, Reaction Time; ACC, accuracy; RAPM, Raven Advanced Progressive Matrix (intelligence); Categorization, Overinclusive Thinking; Number-letter, shifting ability; Operation span, working memory capacity.

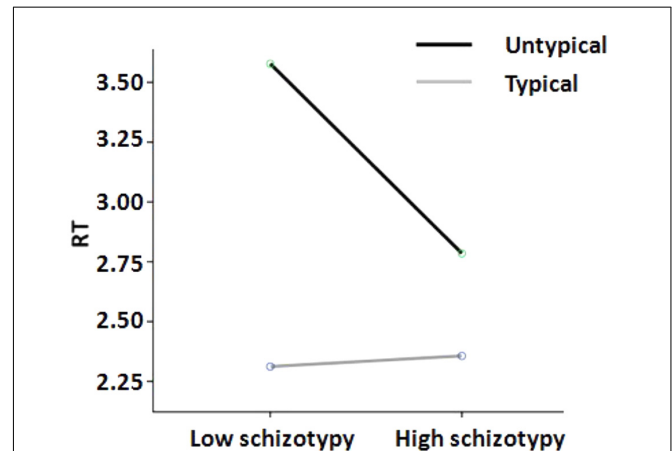
## Group Differences in Creativity Tasks

The results indicated that high schizotypy group scored significantly higher in originality of AUT [ $t_{(76)} = 2.01, p = 0.048$ , Cohen's  $d = 0.46$ ] and marginally significantly higher in fluency of AUT [ $t_{(76)} = 1.90, p = 0.062$ , Cohen's  $d = 0.43$ ] than the low schizotypy group. In addition, the high schizotypy group exhibited significantly higher scores on difference of extraterrestrials task [ $t_{(76)} = 2.92, p = 0.005$ , Cohen's  $d = 0.66$ ] and originality of extraterrestrials task [ $t_{(76)} = 2.46, p = 0.016$ , Cohen's  $d = 0.56$ ] than the low schizotypy group.

## Group Differences in OT Task

Repeated measures ANOVA was employed to assess group differences in RT and rating of categorization task, with between subjects factor being group (low vs. high schizotypy group) and within subjects factor being typicality (typical vs. untypical exemplars). The results showed that the main effect of group on RT of the categorization task was non-significant [ $F_{(1,76)} = 2.37, p = 0.128, \eta_p^2 = 0.03$ ]. However, there was a main effect of typicality on the RT of the categorization task [ $F_{(1,77)} = 21.60, p < 0.001, \eta_p^2 = 0.22$ ], and participants responded faster to typical exemplars ( $M = 2.33$  s,  $SD = 1.08$  s) than to untypical exemplars ( $M = 3.20$  s,  $SD = 1.59$  s). More notably, there was a significant interaction of group and typicality on RT of categorization task [ $F_{(1,76)} = 5.28, p = 0.024, \eta_p^2 = 0.07$ ]. The interaction indicated that the high schizotypy group responded faster for untypical exemplars ( $M = 2.79$  s,  $SD = 1.19$  s) than the low schizotypy group ( $M = 3.58$  s,  $SD = 1.81$  s), while there were no significant group differences for typical exemplars (see **Figure 1**).

In addition, there was a main effect of typicality on rating of categorization task [ $F_{(1,153)} = 571.38, p < 0.001, \eta_p^2 = 0.88$ ], and participants rated higher for typical exemplars than for untypical exemplars. The main effect of group on rating of categorization

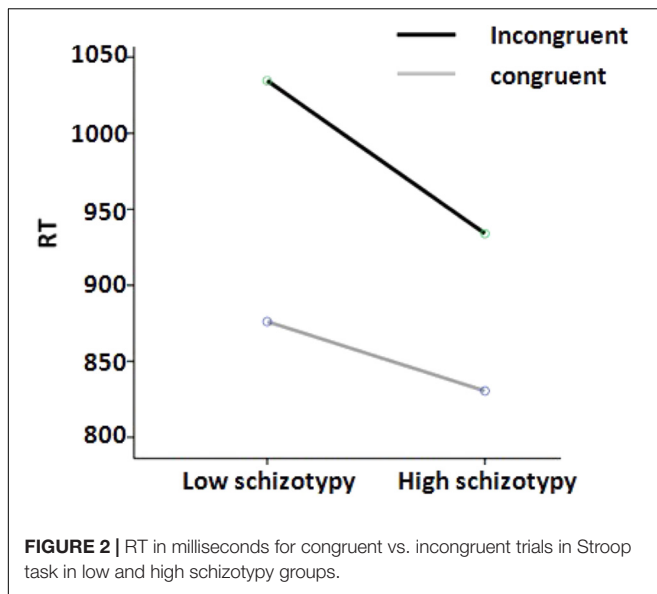


**FIGURE 1** | RT in seconds for untypical vs. typical exemplars in categorization task in low and high schizotypy groups.

task was not significant [ $F_{(1,153)} = 0.22, p = 0.643, \eta_p^2 = 0.003$ ], and the interaction between group and typicality was not significant [ $F_{(1,76)} = 0.72, p = 0.398, \eta_p^2 = 0.01$ ].

## Group Differences in Cognitive Inhibition and Other Executive Functioning Tasks

Concerning cognitive inhibition, repeated measures mixed effects ANOVA was employed to assess group differences in RT and ACC of Stroop interference task, with between subjects factor being group (low vs. high schizotypy group) and within subjects factor being congruence (congruent vs. incongruent trials). The results showed that there was no significant main effect of group on RT of Stroop task [ $F_{(1,76)} = 1.73, p = 0.192, \eta_p^2 = 0.02$ ].



However, there was a main effect of congruence on RT of Stroop task [ $F_{(1,77)} = 196.72, p < 0.001, \eta_p^2 = 0.74$ ]. This indicates a significant Stroop interference effect in that RT was slower for incongruent trials ( $M = 986.88$  ms,  $SD = 268.95$  ms) than congruent trials ( $M = 854.45$  ms,  $SD = 228.45$  ms). More importantly, there was a significant group and congruence interaction on RT of Stroop task [ $F_{(1,76)} = 9.39, p = 0.003, \eta_p^2 = 0.11$ ]. Specifically, the high schizotypy group responded faster for incongruent trials ( $M = 934.01$  ms,  $SD = 236.62$  ms) than the low schizotypy group ( $M = 1034.6$  ms,  $SD = 289.71$  ms), while there were no significant group differences in congruent trials (see **Figure 2**).

For ACC of Stroop interference task, significant main effect of congruence was observed [ $F_{(1,77)} = 150.47, p < 0.001, \eta_p^2 = 0.66$ ] in that there was lower ACC for incongruent trials ( $M = 0.94, SD = 0.04$ ) than for congruent trials ( $M = 0.97, SD = 0.03$ ). Moreover, there was a significant main effect of group on ACC of Stroop task [ $F_{(1,76)} = 5.40, p = 0.023, \eta_p^2 = 0.07$ ] and there was higher ACC in high schizotypy group ( $M = 0.96, SD = 0.02$ ) than in low schizotypy group ( $M = 0.95, SD = 0.04$ ). However, there was no significant interaction between group and congruence on ACC of Stroop task [ $F_{(1,76)} = 0.65, p = 0.42, \eta_p^2 = 0.01$ ]. In addition, there were no significant differences between low- and high-schizotypy groups in RT of number-letter task that measures shifting ability [ $t_{(76)} = 1.14, p = 0.257, \text{Cohen's } d = 0.26$ ], ACC of number-letter task [ $t_{(76)} = 0.34, p = 0.732, \text{Cohen's } d = 0.08$ ], working memory capacity [ $t_{(76)} = 0.98, p = 0.333, \text{Cohen's } d = 0.21$ ], and intelligence [ $t_{(76)} = 0.83, p = .407, \text{Cohen's } d = 0.19$ ].

## Mediation Effects of OT and Cognitive Inhibition Between Schizotypy and Creativity

According to the results of Pearson correlation coefficients among the variables (see **Table 3**), RT of categorization for

untypical exemplars was negatively correlated with originality of AUT ( $r = -0.29, p = 0.010$ ). The rating of categorization for untypical exemplars was positively correlated with fluency of AUT ( $r = 0.27, p = 0.016$ ) and difference of extraterrestrials task ( $r = 0.27, p = 0.019$ ). These results indicated that OT scores tended to be higher for more creative individuals. In contrast, the Stroop interference effect was negatively correlated with the originality of extraterrestrials task ( $r = -0.24, p = 0.037$ ). This indicated that Stroop interference tended to be low and cognitive inhibition tended to be high for more creative individuals.

Three linear regressions and bootstrapping using Hayes macro PROCESS were further performed to establish mediation. In the PROCESS, a Bootstrap sample of 5,000 and Bias Corrected method were used to derive confidence interval for indirect effects. The regression results showed that the outcome variable, originality of AUT, was regressed on the predictor, schizotypy, and the path (Path C<sub>1</sub>) was significant ( $\beta = 0.21, p = 0.048$ ) (see **Figure 3**). The relationship (Path A) between the predictor and mediator variable (i.e., OT) was significant ( $\beta = -0.25, p = 0.027$ ), so was the relationship (Path B) between the mediator and outcome variables ( $\beta = -0.26, p = 0.028$ ). Finally, when the outcome variable, originality of AUT, was regressed on both schizotypy and OT, the prediction effect of schizotypy (Path C<sub>2</sub>) became non-significant ( $\beta = 0.15, p = 0.202$ ). Because the original regression coefficient reduced from 0.21 to 0.15, OT only partially mediated the relationship between schizotypy and originality of AUT. The standardized indirect effect of schizotypy on creativity via OT was significant, with the effect size being 0.03 [95% CI = 0.003, 0.085].

The same analysis was used to assess the mediation effect of cognitive inhibition (i.e., Stroop interference effect) between schizotypy and creativity. Similar results were found, showing that cognitive inhibition partially mediated the relationship between schizotypy and originality of extraterrestrials task. However, the mediation role of the rating of categorization for untypical exemplars was not found because there was no significant difference between low and high schizotypy group in this variable. The standardized indirect effect of schizotypy on creativity via cognitive inhibition was significant, with the effect size being larger (0.18) than the effect of OT [95% CI = 0.029, 0.471].

## DISCUSSION

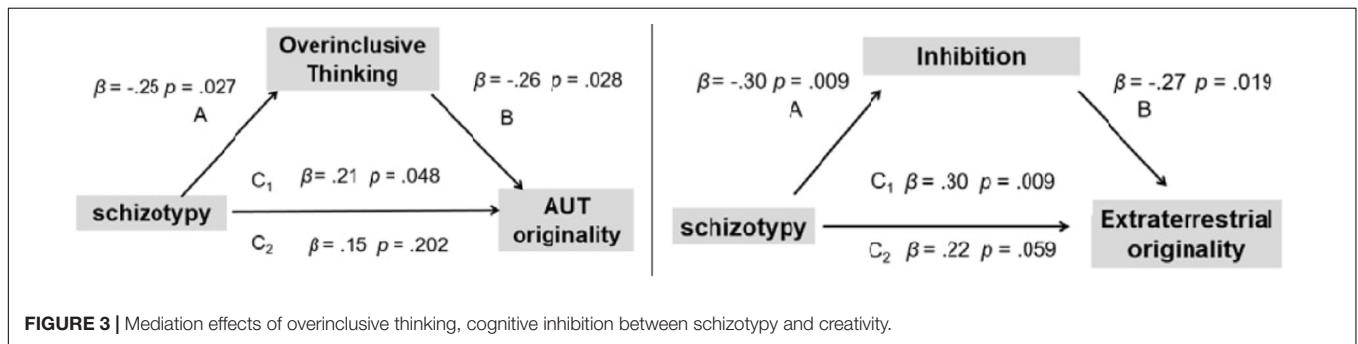
The current study examined the relationship among schizotypy, creativity, OT, and cognitive inhibition ability and found that high schizotypal individuals performed better on creativity tasks and had higher OT and cognitive inhibition. In addition, higher creativity was correlated with higher OT and cognitive inhibition. More notably, OT and cognitive inhibition partially mediated the relationship between schizotypy and creativity. These findings support our hypotheses on the relationships among these variables.

The study showed that high schizotypal individuals had higher OT as indicated by faster RT of typicality rating for untypical exemplars in categorization task. This suggests that

**TABLE 3 |** Correlations between overinclusive thinking, cognitive inhibition, executive functioning, and creativity measures.

	1	2	3	4	5	6	7	8	9	10	11	12
(1) AUT Originality												
(2) AUT Fluency	0.03											
(3) Extrat Difference	-0.01	0.221										
(4) Extrat Originality	0.06	0.21	0.38**									
(5) Categor. RT : untypical	-0.29*	-0.07	0.02	-0.11								
(6) Categor. Rating : untypical	0.11	0.27*	0.27*	0.16	-0.07							
(7) Stroop inter. effect	-0.18	-0.13	-0.01	-0.24*	-0.00	0.04						
(8) Stroop ACC	-0.03	-0.12	-0.04	0.06	0.16	0.08	-0.21					
(9) Number-letter RT	0.13	-0.01	0.01	0.10	0.08	0.02	0.15	-0.14				
(10) Number-letter ACC	-0.05	-0.15	-0.06	0.10	0.23*	0.01	0.12	0.61**	0.11			
(11) Operation span	0.05	0.11	0.11	-0.14	0.07	0.11	0.04	0.16	0.27*	0.00		
(12) RAPM	0.21	0.01	0.17	0.14	0.05	0.08	-0.26*	0.08	-0.23*	0.00	0.27*	

\* $p < 0.05$ . \*\* $p < 0.01$ . Extrat., Extraterrials; Categor., Categorization; AUT, Alternative Uses Test; Extraterrials, creativity task; Categorization, Overinclusive Thinking task; Stroop, cognitive inhibition task; Number-letter, shifting ability task; Operation span, working memory capacity task; RAPM, intelligence task.



**FIGURE 3 |** Mediation effects of overinclusive thinking, cognitive inhibition between schizotypy and creativity.

high schizotypal individuals displayed advantages in automatic creative thinking process. This result is in line with previous findings. For example, Gianotti et al. (2001) found that individuals with high paranormal belief scores spent less association latency when generating words semantically related to given word pairs. Mohr et al. (2001) also reported that high schizotypy group measured by magical ideation were more likely to rate closer semantic relationship for unrelated or indirectly related word pairs than the low schizotypy group, which implies that high schizotypal individuals have the capacity of broadening conceptual boundary as reflected by higher OT.

The study also demonstrated that OT tended to be higher for individuals with more creative performance as indicated by originality and fluency of AUT as well as difference of extraterrestrials task. This positive association may be because OT, as a type of remote association ability, enabled individuals to produce a connection between remote semantic networks, thus, generating more original ideas (Mohr and Claridge, 2015). Moreover, individuals with better AUT performance showed faster judgment for the relatedness of the concepts and this speed advantage may contribute to the concept selection, which results in creative ideation (Vartanian et al., 2009).

The study further revealed that high schizotypal individuals tended to have higher cognitive inhibition as indicated by reduced Stroop interference effect. That is, higher cognitive inhibition was positively correlated with better creativity

performance. This suggests that high schizotypal individuals are more likely to engage in the effortful/controlled creative thinking process. These results further replicate some of the previous studies. For instance, higher cognitive inhibition leads to higher creative performance in problem solving (Cassotti et al., 2016) and higher cognitive inhibition indicated by lower Stroop interference effect were positively correlated with better originality and fluency of creativity scores obtained from Torrance Tests of Creative Thinking (Edl et al., 2014). The reduced Stroop interference effect found in the study may be explained by the reduction in the effect of the regularities of the past experiences on the current perception, a mechanism called dissociation information process (Hemsley, 1993).

The results of this study further showed that other executive functions, including shifting ability, working memory capacity, and intelligence, were not significant predictors of creativity of high schizotypal individuals. However, they may serve as protective factors for these individuals so that they become people with creative potential rather than those with psychosis. This notion finds support from a previous review on shared vulnerability model of creativity and psychopathology, which suggested that highly creative individuals are protected by factors such as intelligence, working memory, and cognitive flexibility to make enlarged stimuli in conscious awareness that is manipulated and combined to generate unique ideas (Carson, 2011).

The most interesting findings of the current study were the partial mediation effects of OT and cognitive inhibition on the relationship between schizotypy and creativity. It is noted that better performance on AUT required the retrieval and combination of distantly related information (Fink et al., 2014b). Therefore, individuals with high OT might benefit from loose conceptual boundary and activate remote concepts when working on AUT. This mediation effect of OT on creativity also confirms the findings of a recent study, which indicated the increase of participants' originality and fluency in the Torrance Creative Thinking Test after a training on OT (Chiu, 2015). Ward's (1994) study also found that participants tend to generate imagined creatures with typical properties of animals on the Earth after the prompt of structured imagination. However, cognitive inhibition might supervise the originality of generated ideas and exclude common ideas (Beaty and Silvia, 2012; Edl et al., 2014). Thus, individuals with high cognitive inhibition could suppress the ordinary responses and retain the unique ones that are produced in creativity tasks. Therefore, high schizotypal individuals who have higher cognitive inhibition could override the existing category knowledge of the Earth creatures to produce more original extraterrestrials than did low schizotypal individuals (Ward, 1994).

The partial mediation effects of both OT and cognitive inhibition on the relationship between schizotypy and creativity further suggest that both cognitive processes, automatic/associative and effortful/controlled processes are involved in creativity performance of high schizotypal individuals. The results lend support for the dual process of creative thinking that highlights the important roles of these two processes in creative cognition (Allen and Thomas, 2011; Beaty et al., 2014, 2016). However, these two underlying processes may perform differently in specific stages and contexts of creative thinking (Allen and Thomas, 2011; Cheng et al., 2016). The automatic/associative process may drive response generation and problem searching, while effortful/controlled process may work on response evaluation and solution refining (Allen and Thomas, 2011; Beaty et al., 2016). Because AUT predominantly relies on idea generation (Radel et al., 2015), it might not be surprising to find that OT partially mediated the effect of schizotypy on creativity assessed by AUT. However, on the other hand, extraterrestrials task might require more response evaluation than response generation. Therefore, participants have to suppress the existing mental representation and category properties of Earth creatures when instructed to produce unique extraterrestrials that were different from Earth creatures (Ward, 1994). Moreover, individuals were more likely to employ automatic/associative process when completing tasks in a constrained length of time (Evans and Curtis-Holmes, 2005; Allen and Thomas, 2011). Because this study provided relatively longer time for extraterrestrials task (20 min) than for AUT (3 min), high schizotypal individuals might employ a more effortful/controlled process in extraterrestrials task than in AUT. This could avoid the "path of least resistance" (i.e., generate highly accessible ideas with least possible effort) and lead to a lower level of originality (Nijstad et al., 2010).

However, this may also be related to the effect of speededness as recent studies have confirmed that less creative ideas were generated under the speeded condition and that the speededness is a significant predictor for mental speed shown in divergent thinking tasks (Preckel et al., 2011; Forthmann et al., in press).

There are a couple of limitations in the current study. First, the study only focused on two links that have been widely discussed in the field, OT and cognitive inhibition. Future research should investigate other potential links to these variables, such as, experience regression, unusual experiences (Acar and Sen, 2013), and neural hyper-connectivity (Carson, 2011). Second, the study employed a convenience sample and the generalizability of the results may be limited. In addition, the upper and lower 10% quantiles used to identify high- and low-schizotypy individuals for the sample might not reflect the base rate of a general population. Third, LI, as another mechanism to explain the link between schizotypy and creativity, was not examined simultaneously with Stroop interference effect. This is due to the following two considerations. First, this study aimed to explore the potential role of OT from the perspective of automatic/associative creative cognition and the role of cognitive inhibition from the perspective of effortful/controlled creative cognition. Second, too many tests may cause fatigue among participants and reduce accuracy in task completion.

## Implications for Rehabilitation

Creative people tend to be described as people with mental illness (Andreasen, 1987; Macnaughton and Saunders, 2005; Glazer, 2009; Silvia and Kaufman, 2010; Kaufman, 2014). Schizophrenia, schizotypy personality disorder, and bipolar disorders are mental illnesses that are often thought to be closely related to creativity (Michalica and Hunt, 2013; Kaufman, 2014). Prior research has found the connection between creativity and these mental problems. It indicated that individuals who score high on schizotypy questionnaires tend to have unusual perceptions, odd ideas, inappropriate behaviors, and psychotic-like experiences. They are more likely to be described as eccentric than average people (Chapman et al., 1976; Eckblad and Chapman, 1983; Claridge, 1997; Fisher et al., 2004; Michalica and Hunt, 2013).

Individuals with schizophrenia or schizotypy show various degrees of deficits in many aspects, including cognitive, psychophysiological, neuro-psychological, personality, and morphological (Trestman et al., 1995; Park and McTigue, 1997). Because of these deficits, they show different symptoms, depending on the severity of the problems. For instance, they may experience hallucinations, delusions, magical thinking, social withdrawal, attentional difficulties, neuroticism, asocial behaviors, and impulsiveness (Claridge et al., 1996; Brod, 1997; Michalica and Hunt, 2013).

Over the past several decades, rehabilitation programs have been developed to treat the impairment and symptoms of individuals with schizophrenia or schizotypy. For instance, Spaulding et al. (1994) employed a three-factor model to assess and treat cognitive and neuropsychological impairments in

schizophrenia, including a vulnerability-linked first factor, episode-linked second factor, and psychosocial-amenable third factor. Sartory et al. (2003) implemented an adaptive, computerized training program with 42 patients having chronic schizophrenia for 45 sessions and found significant improvement in the attention, executive function, and verbal learning of the treatment group. Levaux et al. (2009) reported the success of the use of cognitive and ecological exercises in improving the schizophrenia patient's sub-component of working memory.

However, the extensive impairment and symptoms of schizophrenia and schizotypal individuals pose challenges to the rehabilitation, evidenced by several unsuccessful interventions (Pilling et al., 2002; Silverstein and Wilkniss, 2004). Most of the past interventions employed cognitive rehabilitation approaches and mainly focused on cognitive impairments, which may negatively influence the effectiveness of the treatments. Silverstein and Wilkniss (2004) noted that schizophrenia rehabilitation should systematically address other aspects, such as "motivation, self-esteem, and affective factors" (p. 679). The findings in the current and previous studies have consistently suggested that creativity functions as a protective factor that buffers individuals from negative influences. Although there are overlaps between creativity and schizophrenia and schizotypy, creative people are not always disorganized, asocial, or antisocial. In other words, there are ways that creative people use their unusual experiences constructively (Michalica and Hunt, 2013). It has also been indicated in the past research that creativity and creative thinking are important and effective coping strategies for individuals to become more resilient, particularly when faced with setbacks and difficulties (Carson et al., 1994; Davey et al., 2003; Edward and Warelow, 2005; Kitano and Lewis, 2005). Therefore, integrating creativity or creative

activities in the future rehabilitation programs for schizophrenia and schizotypy may effectively reduce the symptoms and disorders.

## ETHICS STATEMENT

This study was carried out in accordance with the recommendations of the guidelines of the Institutional Research Board at East China Normal University with written informed consent from all subjects. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the Institutional Research Board at East China Normal University.

## AUTHOR CONTRIBUTIONS

LW designed the study, collected and analyzed the data, and wrote the paper. HL interpreted the results and wrote and revised the paper. JP revised the paper. QW wrote and revised the paper. XX collected and analyzed the data. WP provided the idea of the study, interpreted the results, and revised the paper.

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## REFERENCES

- Abraham, A., and Windmann, S. (2008). Selective information processing advantages in creative cognition as a function of schizotypy. *Creat. Res. J.* 20, 1–6. doi: 10.1080/10400410701839819
- Abraham, A., Windmann, S., McKenna, P., and Güntürkün, O. (2007). Creative thinking in schizophrenia: the role of executive dysfunction and symptom severity. *Cogn. Neuropsychiatry* 12, 235–258. doi: 10.1080/13546800601046714
- Acar, S., Chen, X., and Cayirdag, N. (2018). Schizophrenia and creativity: a meta-analytic review. *Schizophr. Res.* 195, 23–31. doi: 10.1016/j.schres.2017.08.036
- Acar, S., and Runco, M. A. (2012). Psychoticism and creativity: a meta-analytic review. *Psychol. Aesthet. Creat. Arts* 6, 341–350. doi: 10.1016/j.schres.2017.08.036
- Acar, S., and Sen, S. (2013). A multilevel meta-analysis of the relationship between creativity and schizotypy. *Psychol. Aesthet. Creat. Arts* 7, 214–228. doi: 10.1037/a0031975
- Allen, A. P., and Thomas, K. E. (2011). A dual process account of creative thinking. *Creat. Res. J.* 23, 109–118. doi: 10.1002/cad.20153
- Amabile, T. M. (1982). Socialpsychology of creativity: a consensual assessment technique. *J. Pers. Soc. Psychol.* 43, 997–1013. doi: 10.1037/0022-3514.43.5.997
- Andreasen, N. C. (1987). Creativity and mental illness: prevalence rates in writers and their first-degree relatives. *Am. J. Psychiatr.* 144, 1288–1292. doi: 10.1176/ajp.144.10.1288
- Baas, M., Nijstad, B. A., Boot, N. C., and De Dreu, C. K. (2016). Mad genius revisited: vulnerability to psychopathology, biobehavioral approach-avoidance, and creativity. *Psychol. Bull.* 142, 668–692. doi: 10.1037/bul0000049
- Bailey, K., West, R., and Anderson, C. A. (2010). A negative association between video game experience and proactive cognitive control. *Psychophysiology* 47, 34–42. doi: 10.1111/j.1469-8986.2009.00925.x
- Batey, M. D. (2007). *A Psychometric Investigation of Everyday Creativity*. Unpublished doctoral dissertation. London: University College.
- Barrantes-Vidal, N. (2014). "Creativity and the spectrum of affective and schizophrenic psychoses," in *Creativity and Mental Illness*, ed. J. C. Kaufman (Cambridge: Cambridge University Press), 169–204.
- Beaty, R. E., Benedek, M., Silvia, P. J., and Schacter, D. L. (2016). Creative cognition and brain network dynamics. *Trends Cogn. Sci.* 20, 87–95. doi: 10.1016/j.tics.2015.10.004
- Beaty, R. E., and Furnham, A. (2008). The relationship between measures of creativity and schizotypy. *Pers. Individ. Dif.* 45, 816–821. doi: 10.1016/j.paid.2008.08.014
- Beaty, R. E., and Silvia, P. J. (2012). Why do ideas get more creative across time? An executive interpretation of the serial order effect in divergent thinking tasks. *Psychol. Aesthet. Creat. Arts* 6, 309–319. doi: 10.1037/a0029171
- Beaty, R. E., Silvia, P. J., Nusbaum, E. C., Jauk, E., and Benedek, M. (2014). The roles of associative and executive processes in creative cognition. *Mem. Cognit.* 42, 1186–1197. doi: 10.3758/s13421-014-0428-8
- Bedwell, J. S., Hernandez, D. C., and Ranieri, A. Y. (2011). The backward masking red light effect and schizotypy: the influence of sex. *Psychiatry Res.* 189, 228–232. doi: 10.1016/j.psychres.2011.07.018
- Beech, A., Baylis, G. C., Smithson, P., and Claridge, G. (1989). Individual differences in schizotypy as reflected in measures of cognitive inhibition. *Br. J. Clin. Psychol.* 28, 117–129.

- Benedek, M., Franz, F., Heene, M., and Neubauer, A. C. (2012a). Differential effects of cognitive inhibition and intelligence on creativity. *Pers. Individ. Dif.* 53, 480–485. doi: 10.1016/j.paid.2012.04.014
- Benedek, M., Könen, T., and Neubauer, A. C. (2012b). Associative abilities underlying creativity. *Psychol. Aesthet. Creat. Arts* 6, 273–281. doi: 10.1037/a0027059
- Benedek, M., Jauk, E., Sommer, M., Arendasy, M., and Neubauer, A. C. (2014). Intelligence, creativity, and cognitive control: the common and differential involvement of executive functions in intelligence and creativity. *Intelligence* 46, 73–83. doi: 10.1016/j.intell.2014.05.007
- Brod, J. H. (1997). “Creativity and schizotypy,” in *Schizotypy: Implications for Illness and Health*, ed. G. Claridge (New York, NY: Oxford University Press), 276–298.
- Burch, G. S. J., Hemsley, D. R., Pavelis, C., and Corr, P. J. (2006). Personality, creativity and latent inhibition. *Eur. J. Personal.* 20, 107–122. doi: 10.1002/per.572
- Carson, D. K., Bittner, M. T., Cameron, B. R., Brown, D. M., and Meyer, S. S. (1994). Creative thinking as a predictor of school-aged children’s stress responses and coping abilities. *Creat. Res. J.* 7, 145–158. doi: 10.1080/10400419409534520
- Carson, S. H. (2011). Creativity and psychopathology: a shared vulnerability model. *Can. J. Psychiatry* 56, 144–153.
- Cassotti, M., Agogue, M., and Camarda, A. (2016). Inhibitory control as a core process of creative problem solving and idea generation from childhood to adulthood. *New Dir. Child Adolesc. Dev.* 151, 61–72. doi: 10.1002/cad.20153
- Chan, R. C., Xie, W., Geng, F. L., Wang, Y., Lui, S. S., Wang, C. Y., et al. (2016). Clinical utility and lifespan profiling of neurological soft signs in schizophrenia spectrum disorders. *Schizophr. Bull.* 42, 560–570. doi: 10.1093/schbul/sbv196
- Chapman, L. J., Chapman, J. P., and Raulin, M. L. (1976). Scales for physical and social anhedonia. *J. Abnorm. Psychol.* 87, 399–407.
- Chen, W. J., Hsiao, C. K., and Lin, C. C. (1997). Schizotypy in community samples: the three-factor structure and correlation with sustained attention. *J. Abnorm. Psychol.* 106, 649–654.
- Cheng, L., Hu, W., Jia, X., and Runco, M. A. (2016). The different role of cognitive inhibition in early versus late creative problem finding. *Psychol. Aesthet. Creat. Arts* 10, 32–41. doi: 10.1037/aca0000036
- Chiu, F.-C. (2015). Improving your creative potential without awareness: overinclusive thinking training. *Think. Skills Creat.* 15, 1–12. doi: 10.1016/j.tsc.2014.11.001
- Claridge, G. (1997). *Schizotypy: Implications for Illness and Health*. New York, NY: Oxford University Press.
- Claridge, G., and Blakey, S. (2009). Schizotypy and affective temperament: relationships with divergent thinking and creativity styles. *Personal. Individ. Differ.* 46, 820–826. doi: 10.1016/j.paid.2009.01.015
- Claridge, G., McCreery, C., Mason, O., Bentall, R., Boyle, G., Slade, P., et al. (1996). The factor structure of “schizotypal” traits: a large replication study. *Br. J. Clin. Psychol.* 35, 103–115.
- Cox, A. J., and Leon, J. L. (1999). Negative schizotypal traits in the relation of creativity to psychopathology. *Creat. Res. J.* 12, 25–36.
- Crabtree, J., and Green, M. J. (2016). Creative cognition and psychosis vulnerability: what’s the difference? *Creat. Res. J.* 28, 24–32. doi: 10.1080/10400419.2015.1030305
- Davey, M., Eaker, D. G., and Walters, L. H. (2003). Resilience processes in adolescents: personality profiles, self-worth, and coping. *J. Adolesc. Res.* 18, 347–362. doi: 10.1177/0743558403018004002
- Debbane, M., and Mohr, C. (2015). Integration and development in schizotypy research: an introduction to the special supplement. *Schizophr. Bull.* 41(Suppl. 2), 363–365. doi: 10.1093/schbul/sbv003
- Eckblad, M., and Chapman, L. J. (1983). Magical ideation as an indicator of schizotypy. *J. Consult. Clin. Psychol.* 51, 215–225.
- Edl, S., Benedek, M., Papousek, I., Weiss, E. M., and Fink, A. (2014). Creativity and the stroop interference effect. *Personal. Individ. Differ.* 69, 38–42. doi: 10.1016/j.paid.2014.05.009
- Edward, K.-L., and Warelow, P. (2005). Resilience: when coping is emotionally intelligent. *J. Am. Psychiatr. Nurses Assoc.* 11, 101–102.
- Evans, J. S. B. T., and Curtis-Holmes, J. (2005). Rapid responding increases belief bias: evidence for the dual-process theory of reasoning. *Think. Reason.* 11, 382–389. doi: 10.1080/13546780542000005
- Eysenck, H. J. (1993). Creativity and personality: suggestions for a theory. *Psychol. Inquiry* 4, 147–178.
- Fink, A., Benedek, M., Unterrainer, H.-F., Papousek, I., and Weiss, E. M. (2014a). Creativity and psychopathology: are there similar mental processes involved in creativity and in psychosis-proneness? *Front. Psychol.* 5:1211. doi: 10.3389/fpsyg.2014.01211
- Fink, A., Weber, B., Koschutnig, K., Mathias, B., Reishofer, G., Ebner, F., et al. (2014b). Creativity and schizotypy from the neuroscience perspective. *Cogn. Affect. Behav. Neurosci.* 14, 378–387. doi: 10.3758/s13415-013-0210-6
- Fisher, J., Mohanty, A., Herrington, J. D., Koven, N. S., Miller, G., and Heller, W. (2004). Neuropsychological evidence for dimensional schizotypy: implications for creativity and psychopathology. *J. Res. Personal.* 38, 24–31.
- Fisher, J. E. (2015). Challenges in determining whether creativity and mental illness are associated. *Front. Psychol.* 6:163. doi: 10.3389/fpsyg.2015.00163
- Forthmann, B., Gerwig, A., Holling, H., Çelik, P., Storme, M., and Lubart, T. (2016). The be-creative effect in divergent thinking: the interplay of instruction and object frequency. *Intelligence* 57, 25–32.
- Forthmann, B., Holling, H., Çelik, P., Storme, M., and Lubart, T. (2017). Typing speed as a confounding variable and the measurement of quality in divergent thinking. *Creat. Res. J.* 29, 257–269.
- Forthmann, B., Lips, C., Szardenings, C., Scharfen, J., and Holling, H. (in press). Are speedy brains needed when divergent thinking is speeded—or unspeeded? *J. Creat. Behav.*
- Friedman, N. P., and Miyake, A. (2004). The relations among inhibition and interference control functions: a latent-variable analysis. *J. Exp. Psychol. Gen.* 133, 101–135. doi: 10.1037/0096-3445.133.1.101
- Gianotti, L. R., Mohr, C., Pizzagalli, D., Lehmann, D., and Brugger, P. (2001). Associative processing and paranormal belief. *Psychiatry Clin. Neurosci.* 55, 595–603.
- Glazer, E. (2009). Rephrasing the madness and creativity debate: what is the nature of the creativity construct? *Personal. Individ. Differ.* 46, 755–764. doi: 10.1016/j.paid.2009.01.021
- Green, M. J., and Williams, L. M. (1999). Schizotypy and creativity as effects of reduced cognitive inhibition. *Personal. Individ. Differ.* 27, 263–276. doi: 10.1016/S0191-8869(98)00238-4
- Grimshaw, G. M., Bryson, F. M., Atchley, R. A., and Humphrey, M. K. (2010). Semantic ambiguity resolution in positive schizotypy: a right hemisphere interpretation. *Neuropsychology* 24, 130–138. doi: 10.1037/a0016793
- Guilford, J. P. (1967). Creativity: yesterday, today and tomorrow. *J. Creat. Behav.* 1, 3–14.
- Gough, H. G. (1979). A creative personality scale for the Adjective Check List. *J. Pers. Soc. Psychol.* 37, 1398–1405. doi: 10.1037/0022-3514.37.8.1398
- Hao, N. (2010). The effects of domain knowledge and instructional manipulation on creative idea generation. *J. Creat. Behav.* 44, 237–257. doi: 10.1002/j.2162-6057.2010.tb01335.x
- Hao, N., Ku, Y., Liu, M., Hu, Y., Grabner, R. H., and Fink, A. (2014a). Enhancing verbal creativity via brief interventions during an incubation interval. *Creat. Res. J.* 26, 30–38. doi: 10.1080/10400419.2014.873658
- Hao, N., Yuan, H., Hu, Y., and Grabner, R. H. (2014b). Interaction effect of body position and arm posture on creative thinking. *Learn. Individ. Differ.* 32, 261–265. doi: 10.1016/j.lindif.2014.03.025
- Hasenpus, N. A., and Magaro, P. A. (1976). Creativity and schizophrenia: an equality of empirical constructs. *Br. J. Psychiatry* 129, 346–349.
- Hayes, A. F. (2009). Beyond Baron and Kenny: statistical mediation analysis in the new millennium. *Commun. Monogr.* 76, 408–420.
- Heckers, S., Barch, D. M., Bustillo, J., Gaebel, W., Gur, R., Malaspina, D., et al. (2013). Structure of the psychotic disorders classification in DSM-5. *Schizophr. Res.* 150, 11–14. doi: 10.1016/j.schres.2013.04.039
- Hemsley, D. R. (1993). A simple (or simplistic?) cognitive model for schizophrenia. *Behav. Res. Ther.* 31, 633–645.
- Höfer, I., Casa, V. D., and Feldon, J. (1999). The interaction between schizotypy and latent inhibition: modulation by experimental parameters. *Pers. Individ. Dif.* 26, 1075–1088. doi: 10.1016/S0191-8869(98)00211-6

- Jaracz, J., Patrzala, A., and Rybakowski, J. K. (2012). Creative thinking deficits in patients with schizophrenia: neurocognitive correlates. *J. Nerv. Ment. Dis.* 200, 588–593. doi: 10.1097/NMD.0b013e31825bfc49
- Jones, T. L., Caulfield, L., Wilkinson, D., and Weller, L. (2011). The relationship between nonclinical schizotypy and handedness on divergent and convergent creative problem-solving tasks. *Creat. Res. J.* 23, 222–228. doi: 10.1080/10400419.2011.595964
- Kaplan, O., and Lubow, R. E. (2011). Ignoring irrelevant stimuli in latent inhibition and Stroop paradigms: the effects of schizotypy and gender. *Psychiatry Res.* 186, 40–45. doi: 10.1016/j.psychres.2010.07.025
- Karlsson, J. L. (1970). Genetic association of giftedness and creativity with schizophrenia. *Hereditas* 66, 177–181.
- Kaufman, J. C., and Beghetto, R. A. (2009). Beyond big and little: The four C model of creativity. *Rev. Gen. Psychol.* 13, 1–12. doi: 10.1037/a0013688
- Kaufman, J. C. (ed.) (2014). *Creativity and Mental Illness*. New York, NY: Cambridge University Press.
- Kaufman, S. B., and Paul, E. S. (2014). Creativity and schizophrenia spectrum disorders across the arts and sciences. *Front. Psychol.* 5:1145. doi: 10.3389/fpsyg.2014.01145
- Kim, M. S., Oh, S. H., Hong, M. H., and Choi, D. B. (2011). Neuropsychologic profile of college students with schizotypal traits. *Compr. Psychiatry* 52, 511–516. doi: 10.1016/j.comppsy.2010.10.010
- Kitano, M. K., and Lewis, R. B. (2005). Resilience and coping: implications for gifted children. *Roepers Rev.* 27, 200–205. doi: 10.1080/02783190509554319
- Koychev, I., Joyce, D., Barkus, E., Ettinger, U., Schmechtig, A., Dourish, C. T., et al. (2016). Cognitive and oculomotor performance in subjects with low and high schizotypy: implications for translational drug development studies. *Transl. Psychiatry* 6:e811. doi: 10.1038/tp.2016.64
- Kyaga, S., Landén, M., Boman, M., Hultman, C. M., Långström, N., and Lichtenstein, P. (2013). Mental illness, suicide and creativity: 40-year prospective total population study. *J. Psychiatr. Res.* 47, 83–90. doi: 10.1016/j.jpsychires.2012.09.010
- Kyaga, S., Lichtenstein, P., Boman, M., Hultman, C., Långström, N., and Landén, M. (2011). Creativity and mental disorder: family study of 300 000 people with severe mental disorder. *Br. J. Psychiatry* 199, 373–379. doi: 10.1192/bjp.bp.110.085316
- Levaux, M.-N., Vezzaro, J., Laroï, F., Offerlin-Meyer, I., Danion, J.-M., and Van der Linden, M. (2009). Cognitive rehabilitation of the updating sub-component of working memory in schizophrenia: a case study. *Neuropsychol. Rehabil* 19, 244–273. doi: 10.1080/09602010802091829
- Lin, W.-L., and Lien, Y.-W. (2013). The different role of working memory in open-ended versus closed-ended creative problem solving: a dual-process theory account. *Creat. Res. J.* 25, 85–96. doi: 10.1080/10400419.2013.752249
- Long, H. (2014a). An empirical review of research methodologies and methods in creativity studies (2003–2012). *Creat. Res. J.* 26, 427–438.
- Long, H. (2014b). More than appropriateness and novelty: judges' criteria of assessing creative products in science tasks. *Think. Skills Creat.* 13, 183–194. doi: 10.1016/j.tsc.2014.05.002
- Lubow, R. E., Kaplan, O., Abramovich, P., Rudnick, A., and Laor, N. (2000). Visual search in schizophrenia: latent inhibition and novel pop-out effects. *Schizophr. Res.* 45, 145–156.
- Lui, S. S., Shi, Y. F., Au, A. C., Li, Z., Tsui, C. F., Chan, C. K., et al. (2016). Affective experience and motivated behavior in schizophrenia spectrum disorders: evidence from clinical and nonclinical samples. *Neuropsychology* 30, 673–684. doi: 10.1037/neu0000278
- Macnaughton, J., and Saunders, C. (2005). *Madness and Creativity in Literature and Culture*. Basingstoke: Palgrave Macmillan.
- Mason, O., Claridge, G., and Jackson, M. (1995). New scales for the assessment of schizotypy. *Pers. Individ. Dif.* 18, 7–13. doi: 10.1016/0191-8869(94)00132-C
- Mednick, S. A. (1962). The associative basis of the creative process. *Psychol. Rev.* 69, 220–232.
- Meehl, P. E. (1990). Toward an integrated theory of schizotaxia, schizotypy, and schizophrenia. *J. Personal. Disord.* 4, 1–99.
- Michalica, K., and Hunt, H. (2013). Creativity, schizotypality, and mystical experience: an empirical study. *Creat. Res. J.* 25, 266–279. doi: 10.1080/10400419.2013.813780
- Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., and Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "Frontal Lobe" tasks: a latent variable analysis. *Cognit. Psychol.* 41, 49–100. doi: 10.1006/cogp.1999.0734
- Mohr, C., and Claridge, G. (2015). Schizotypy—do not worry, it is not all worrisome. *Schizophr. Bull.* 41(Suppl. 2), S436–S443. doi: 10.1093/schbul/sbu185
- Mohr, C., Graves, R. E., Gianotti, L. R., Pizzagalli, D., and Brugger, P. (2001). Loose but normal: a semantic association study. *J. Psycholinguist. Res.* 30, 475–483.
- Moritz, S., and Mass, R. (1997). Reduced cognitive inhibition in schizotypy. *Br. J. Clin. Psychol.* 36, 365–376.
- Nelson, M. T., Seal, M. L., Pantelis, C., and Phillips, L. J. (2013). Evidence of a dimensional relationship between schizotypy and schizophrenia: a systematic review. *Neurosci. Biobehav. Rev.* 37, 317–327. doi: 10.1016/j.neubiorev.2013.01.004
- Nijstad, B. A., De Dreu, C. K. W., Rietzschel, E. F., and Baas, M. (2010). The dual pathway to creativity model: creative ideation as a function of flexibility and persistence. *Eur. Rev. Soc. Psychol.* 21, 34–77. doi: 10.1080/10463281003765323
- Nusbaum, E. C., and Silvia, P. J. (2011). Are intelligence and creativity really so different?: Fluid intelligence, executive processes, and strategy use in divergent thinking. *Intelligence*, 39, 36–45. doi: 10.1016/j.intell.2010.11.002
- Oertel-Knochel, V., Knochel, C., Rotarska-Jagiela, A., Reinke, B., Prvulovic, D., Haenschel, C., et al. (2013). Association between psychotic symptoms and cortical thickness reduction across the schizophrenia spectrum. *Cereb. Cortex* 23, 61–70. doi: 10.1093/cercor/bhr380
- Paek, S. H., Abdulla, A. M., and Cramond, B. (2016). A meta-analysis of the relationship between three common psychopathologies—ADHD, anxiety, and depression—and indicators of little-c creativity. *Gift. Child Q.* 60, 117–133.
- Park, S., and McTigue, K. (1997). Working memory and the syndromes of schizotypal personality. *Schizophr. Res.* 26, 213–220.
- Payne, R. W., and Friedlander, D. (1962). A short battery of simple tests for measuring overinclusive thinking. *Br. J. Psychiatry* 108, 362–367.
- Pilling, S., Bebbington, P., Kuipers, E., Garety, P., Geddes, J., Martindale, B., et al. (2002). Psychological treatments in schizophrenia: II. Meta-analyses of randomized controlled trials of social skills training and cognitive remediation. *Psychol. Med.* 32, 783–791.
- Preckel, F., Wermer, C., and Spinath, F. M. (2011). The interrelationship between speeded and unspeeded divergent thinking and reasoning, and the role of mental speed. *Intelligence* 39, 378–388.
- Radel, R., Davranche, K., Fournier, M., and Dietrich, A. (2015). The role of (dis)inhibition in creativity: decreased inhibition improves idea generation. *Cognition* 134, 110–120. doi: 10.1016/j.cognition.2014.09.001
- Raine, A. (1991). The SPQ: a scale for the assessment of schizotypal personality based on DSM-III-R criteria. *Schizophr. Bull.* 17, 555–564.
- Rawlings, D., and Toogood, A. (1997). Using a 'taboo response' measure to examine the relationship between divergent thinking and psychoticism. *Pers. Individ. Dif.* 22, 61–68. doi: 10.1016/S0191-8869(96)00177-8
- Rominger, C., Papousek, I., Fink, A., and Weiss, E. M. (2013). Enhancement of figural creativity by motor activation: effects of unilateral hand contractions on creativity are moderated by positive schizotypy. *Laterality* 19, 424–438. doi: 10.1080/1357650X.2013.858725
- Rominger, C., Weiss, E. M., Fink, A., Schuller, G., and Papousek, I. (2011). Allusive thinking (cognitive looseness) and the propensity to perceive "meaningful" coincidences. *Personal. Individ. Dif.* 51, 1002–1006. doi: 10.1016/j.paid.2011.08.012
- Runco, M. A. (1991). *Divergent Thinking*. Norwood, NJ: Ablex Publishing.
- Rybakowski, J. K., and Klonowska, P. (2011). Bipolar mood disorder, creativity and schizotypy: an experimental study. *Psychopathology* 44, 296–302. doi: 10.1159/000322814
- Sartory, G., Zorn, C., Groezinger, G., and Windgassen, K. (2003). Cognitive rehabilitation in schizophrenia. *Schizophr. Res.* 60(Suppl.1):155. doi: 10.1016/S0920-9964(03)80991-X
- Schmajuk, N., Aziz, D. R., and Bates, M. J. B. (2009). Attentional-associative interactions in creativity. *Creat. Res. J.* 21, 92–103. doi: 10.1080/10400410802633574
- Schulberg, D., French, C., Stone, B. L., and Heberle, J. (1988). Creativity and schizotypal traits. Creativity test scores and perceptual aberration, magical ideation, and impulsive nonconformity. *J. Nerv. Ment. Dis.* 176, 648–657.

- Silverstein, S. M., and Wilkniess, S. M. (2004). At issue: the future of cognitive rehabilitation of schizophrenia. *Schizophr. Bull.* 30, 679–692.
- Silvia, P. J., and Kaufman, J. C. (2010). "Creativity and mental illness," in *The Cambridge Handbook of Creativity*, eds J. C. Kaufman and R. J. Sternberg (New York, NY: Cambridge University Press), 381–394.
- Spaulding, W. D., Sullivan, M., Weiler, M., Reed, D., Richardson, C., and Storzbach, D. (1994). Changing cognitive functioning in rehabilitation of schizophrenia. *Acta Psychiatr. Scand.* 90, 116–134.
- Taylor, C. L. (2017). Creativity and mood disorder: a systematic review and meta-analysis. *Perspect. Psychol. Sci.* 12, 1040–1076. doi: 10.1177/1745691617699653
- Trestman, R. L., Keefe, R. S. E., Mitropoulou, V., Harvey, P. D., deVegvar, M. L., Lees-Roitman, S., et al. (1995). Cognitive function and biological correlates of cognitive performance in schizotypal personality disorder. *Psychiatry Res.* 59, 127–136.
- Vartanian, O., Martindale, C., and Matthews, J. (2009). Divergent thinking ability is related to faster relatedness judgments. *Psychol. Aesthet. Creat. Arts* 3, 99–103. doi: 10.1037/a0013106
- Wang, L., Xu, X., Wang, Q., Healey, G., Su, L., and Pang, W. (2017). Are individuals with schizophrenia or schizotypy more creative? Evidence from multiple tests of creative potential. *Creat. Res. J.* 29, 145–156. doi: 10.1080/10400419.2017.1302777
- Ward, T. B. (1994). Structured imagination: The role of category structure in exemplar generation. *Cogn. Psychol.* 27, 1–40.
- Ward, T. B., Patterson, M. J., and Sifonis, C. M. (2004). The role of specificity and abstraction in creative idea generation. *Creat. Res. J.* 16, 1–9. doi: 10.1207/s15326934crj1601\_1

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# Problem Space Matters: Evaluation of a German Enrichment Program for Gifted Children

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We studied the development of cognitive abilities related to intelligence and creativity ( $N = 48$ , 6–10 years old), using a longitudinal design (over one school year), in order to evaluate an Enrichment Program for gifted primary school children initiated by the government of the German federal state of Rhineland-Palatinate (*Entdeckertag Rheinland Pfalz*, Germany; ET; Day of Discoverers). A group of German primary school children ( $N = 24$ ), identified earlier as intellectually gifted and selected to join the ET program was compared to a gender-, class- and IQ- matched group of control children that did not participate in this program. All participants performed the Standard Progressive Matrices (SPM) test, which measures intelligence in well-defined problem space; the Creative Reasoning Task (CRT), which measures intelligence in ill-defined problem space; and the test of creative thinking-drawing production (TCT-DP), which measures creativity, also in ill-defined problem space. Results revealed that problem space matters: the ET program is effective only for the improvement of intelligence operating in well-defined problem space. An effect was found for intelligence as measured by SPM only, but neither for intelligence operating in ill-defined problem space (CRT) nor for creativity (TCT-DP). This suggests that, depending on the type of problem spaces presented, different cognitive abilities are elicited in the same child. Therefore, enrichment programs for gifted, but also for children attending traditional schools, should provide opportunities to develop cognitive abilities related to intelligence, operating in both well- and ill-defined problem spaces, and to creativity in a parallel, using an interactive approach.

**Keywords:** cognitive development, giftedness, reasoning, childhood, gifted education, problem space

## INTRODUCTION

Early concepts of giftedness were solely based on the construct of intelligence (e.g., Terman, 1916). Even today, in practice, a single IQ-threshold of 130 is commonly used for the diagnosis of giftedness (Robinson, 2005; Sternberg et al., 2011). Assuming that, across individuals in a population, intelligence is normally distributed according to this criterion, i.e., two standard deviations above the average of  $IQ = 100$ , between 2 and 3% of the population should be considered intellectually gifted.

Giftedness later became a more complex concept and is now considered a multifaceted construct. Rather than with a single measure of intelligence (Reis and Renzulli, 2011), other abilities should be considered as well (e.g., Brown et al., 2005; Reis and Renzulli, 2011; Sternberg et al., 2011). Many theories embrace creativity as an essential component of giftedness (e.g., Runco, 1993); “creativity moves from being a background player to occupying a key role within the context of giftedness and gifted education” (Kaufman et al., 2012, p. 60). For example, two of the most prominent theories of giftedness include the construct of creativity: Renzulli’s Three-Ring Conception (Renzulli, 1978, 2005) and Sternberg’s WICS Model of Giftedness (Sternberg, 2005a,b, 2010).

Some authors argued that there may be different categories or types of giftedness (Renzulli, 1982, 2005; Milgram, 1990; Sternberg, 1990). Sternberg (1990), for instance, suggests that it is necessary to go beyond the view of giftedness as a composite of components, to the view where there are types of giftedness with multiple components each. Renzulli (1982) suggests that there are two types of giftedness: *the schoolhouse giftedness* and *the creative-productive giftedness*, whereas Milgram (1990) suggests that there are four different categories of giftedness: *general intellectual ability or overall general intelligence*, *specific intellectual ability*, *general original/creative thinking*, and *specific creative talent*.

Although there is lack of agreement concerning the concept of giftedness, there is broad consensus among researchers about the importance of giftedness education (Robinson, 2005). Gifted students require challenging educational experiences with other gifted students in order to learn and develop at their own level of aptitude (Mönks and Heller, 1994; Feldhusen, 2005; Robinson, 2005). Reviewing literature on the topic, Reis and Renzulli (2011) reported two main aspects regarding the necessity for developing special programs for gifted children: (1) their needs have not been met in traditional school curricula; (2) they benefit from programs that group them together with the educational purpose to meet their needs.

Interventions with gifted students can be made by offering programs of acceleration and enrichment within homogeneous or heterogeneous grouping (Mönks and Heller, 1994). The acceleration program usually offers learning activities that take into consideration the child’s abilities and speed of processing level, which probably will differ from that of his or her classmates; whereas the enrichment program commonly comprises activities that are, or at least should be, challenging and that go wider and deeper on the topics presented. The activities should cover subjects that typically are not addressed in traditional school curriculum (Mönks and Heller, 1994). According to Reis and Renzulli (2011), a combination of both acceleration and enrichment programs is the best option. Nevertheless, along with teaching methods and curriculum, the evaluation of the program needs to be included among the central issues for improving the quality of education offered to gifted students (Gallagher, 1988). According to Hunsaker and Callahan (1993), the evaluation of a giftedness program should offer meaningful feedback to improve the program’s performance.

While not all children have the capacity to delve wider and deeper into the topics, improving the quality of education in

terms of challenging activities and consideration for individual abilities is essential to all learners and should not be restricted to gifted children. The present study, however, aims to evaluate an enrichment program designed for children identified as gifted, the *Entdeckertag Rheinland-Pfalz* (ET; Day of Discoverers). The ET is a pilot program implemented by the Ministry for Education, Science, Youth and Culture of the German federal state of Rhineland-Palatinate (in the southwest of Germany) in an attempt to recognize and support gifted children in primary school (see section “Materials and Methods”).

Since intelligence and creativity are considered as important components of giftedness, we applied a standardized test of general intelligence and a standardized test of creativity for the evaluation of the enrichment program, using a longitudinal design. The intelligence test measures cognitive processes operating in a well-defined problem space while the creativity test measures cognitive processes operating in an ill-defined problem space. Problem space is an abstract representation of the encountered problem in the mind of the problem solver, containing all possible and/or logical steps to be taken in order to find a final solution (Newell and Simon, 1972). Whereas in well-defined problem space there is only one correct solution, in an ill-defined problem space there are numerous and more idiosyncratic solutions, which can, depending on a certain criterion, be more or less good. Apart from measuring cognition in different problem spaces, the two tests use different knowledge domains: in the intelligence test cognition operates in the domain of relations between geometrical components, in the creativity test, cognition operates in an idiosyncratic domain. Therefore, we additionally applied the Creative Reasoning Task (CRT; Jaarsveld et al., 2010, 2012). The CRT measures intelligence in an ill-defined problem space while operating in the same knowledge domain then the general intelligence test used in the present study.

Studies with the CRT showed, firstly, that scores from a task measuring intelligence in a well-defined problem space (Standard Progressive Matrices; SPM, Raven, 1998) do not correlate with scores from a task measuring intelligence in an ill-defined problem space (CRT), although both tasks use an identical knowledge domain: relations among geometrical components in a small matrix. In this first version of the CRT, scores are based on the frequency of relations applied in the matrix. Results showed that 4–12-year-old children applied these relations with different frequencies depending on the task (Jaarsveld et al., 2010).

Secondly, Jaarsveld et al. (2012) showed that in the CRT both convergent and divergent thinking are applied and can be assessed independently. This second version of the CRT contained a score for convergent and one for divergent thinking. The convergent sub-score evaluates not only the number of relations but also their complexity and whether a relation was applied over all rows and columns of the matrix. This method produces a larger range of score values and therefore provides more differentiated information of reasoning abilities. Using this new scoring method it was shown that from Grade 1 to 4 the CRT sub-score for convergent production correlated with the SPM while the CRT sub-score for divergent production correlated

with the Test for Creative Thinking–Drawing Production (TCT–DP, *Test zum Schöpferisches Denken–Zeichnerisch*, Urban and Jellen, 1995). This suggests that intelligence measured for ill-defined problem space cooperates with creative thinking. This cooperation is also evident in EEG data from the CRT process in terms of an intertwining of convergent and divergent production (Jaarsveld et al., 2015). These results show that intelligence in ill-defined problem space is distinct from intelligence in well-defined space, even when knowledge domain is controlled.

Finally, Welter et al. (2017) found that across primary school cognitive processes in well-defined problem space develop differently from those in ill-defined space. They showed that traditional intelligence test scores (well-defined problem space) increased linearly with grade level, whereas scores from a creativity test (TCT–DP) and those from the CRT sub-score for convergent production (both ill-defined problem space) developed in the same irregular pattern.

From these studies, we can conclude that systematic comparisons between intelligence operating in well- versus ill-defined problem space are more meaningful when cognition in both problem spaces operates in an identical knowledge domain. This, however, is not the case in the majority of studies comparing measures from traditional intelligence and creativity tests (see Jaarsveld and Lachmann, 2017, for an overview).

In sum, the main purpose of the present study is to evaluate the effectiveness of the ET program in improving intelligence and creative abilities of primary school children over the stretch of one school year. We applied three tests, one test measuring intelligence in a well-defined problem space and one test measuring intelligence in an ill-defined problem space, both using the same knowledge domain, and the third one, measuring creativity in an ill-defined problem space. An increase in performance on all three tests would indicate that the ET program adjusted its teaching method and curriculum, promoting cognitive abilities that allow an individual to effectively navigate and operate in both well- and ill-defined problem spaces.

## MATERIALS AND METHODS

### Enrichment Program

#### General Proposal and Guidelines

The *Entdeckertag Rheinland-Pfalz (ET; Day of Discoverers in Rhineland Palatinate)* is an enrichment program for gifted children. It was implemented in 2004 by the Ministry for Education, Science, Youth and Culture of the federal state of Rhineland-Palatinate, Germany. The ET takes place on one fixed day of the week, from 8 am to 4 pm. On this day participating children (ET-children), instead of their normal class, they attend one of the ET classes. The program is conducted in select primary schools across the state, which agreed to offer the training to the ET-children, including those from different schools of the region, in addition to their traditional education scheme. This means that in order to participate the majority of the ET-children need to visit a different school once per week. The ET-children are supposed to catch up on what was taught that day in their

normal class. The ET classes are of mixed grade levels, divided only roughly by age into “younger” (5–7/8 years) and “older” (7/8–10 years). A statistical analyses for 2010/2011 of the federal ministry (Ministry for Education, Science, Youth and Culture of the State Rhineland-Palatinate, 2011) showed that over 6 years 424 children (276 males and 148 females) from 206 primary schools participated in the program at 13 ET schools.

The main objective of the ET program, according to the ministry (Ministry for Education, Science, Youth and Culture of the State Rhineland-Palatinate, 2009), is the early intervention for children with exceptional cognitive abilities to give support and pose challenges in the areas of language and science. According to the ministry, ET-children should experience suitable learning environments that support their cognitive abilities, promote their personality development and strengthens teamwork and social skills.

The ministry provides guidelines for the selection processes and general rules and aims as a kind of curriculum for ET classes (Ministry for Education, Science, Youth and Culture of the State Rhineland-Palatinate, 2009). These include a general agenda about the structure and the course of a day that the participating schools should follow (see **Table 1**). However, schools are free to develop their own proposal within the program’s scope. For example, the ET curriculum requires that children learn an additional foreign language that is not part of the traditional school curriculum, such as Russian or Japanese. What language this will be is, however, the choice of the ET school. Each ET school forms a team of experts that is responsible for the local implementation and organization of the ET program and the diagnostic selection process. This ET team consists of teachers that were previously trained to meet the purpose of the program and to recognize and foster an active, creative, and inquisitive thinking attitude among the gifted children.

In Germany, every child receives free education, which is of high quality, but mainly uses a traditional teacher-directed lesson

**TABLE 1** | Daily structure of the *Entdeckertag* Program.

Time		Daily Structure*
From	To	
8:00	09:30	Work on Topic 1 (mathematics, natural sciences or German language)
09:30	10:30	Work on Topic 2 (language learning or task packages)
10:30	12:00	Research-based learning to self-selected projects
12:00	13:00	Sports, games, planned leisure activities, reading or computer work
13:00	13:30	Lunch and free time
13:30	13:45	Outdoors activities
13:45	16:00	Afternoon projects possibly with extracurricular experts

\*Time interval can be interpreted as a flexible framework for the *Entdeckertag*. This also applies to the intermediate break times that are not listed separately. Adapted from “*Erkennen und Fördern hochbegabter Kinder in der Grundschule: Entdeckertag – Modellprojekt des Landes Rheinland-Pfalz*” by Ministry for Education, Science, Youth and Culture of the State Rhineland-Palatinate (2009), [www.grundschule.bildung-rp.de](http://www.grundschule.bildung-rp.de).

format. In contrast to this traditional schooling, the ET program aims to offer a variety of more *self-directed learning* opportunities. The focus is on individual “research projects”; each child chooses one topic within a given scope. The child should be able to structure the gathered information and present it to classmates and parents as a poster, including pictures and text, or as a power point presentation. During the research phase, children should have the opportunity to discuss issues about their topic with other children in a plenary meeting in order to get comments and suggestions (Baudson, 2009). In addition to the project work, children can work on brainteasers and applied science problems. Moreover, sports and arts are included in the curriculum in order to promote an integrated educational approach (Emrich et al., 2007).

An important element of the ET curriculum are the so called “work packages.” These consist of tasks and activities that the children bring with them to their normal classes to work on during the rest of the week. These include reading and writing tasks, puzzles and arithmetic problems. Gifted children might feel bored during their normal classes because they usually already have a rich knowledge on many topics. Thus, the work packages are helpful in providing continuous challenges to these children. Moreover, these packages help to establish a bridge between both learning environments normal class and ET class, as the child takes the work packages back to traditional school and works on them after finishing regular activities. The teacher can also use this supplemental material as a challenge for children who are not in the ET program. Thus, the work packages help teachers to offer challenging learning activities to all children and therefore enriches future teaching in normal classes independent from the ET program (Emrich et al., 2007).

The selection process is carried out by the ET team of each school. The steps are as follows (Baudson, 2009; Ministry for Education, Science, Youth and Culture of the State Rhineland-Palatinate, 2009): (1) The parents, and/or the relevant teacher, who assume a child to be gifted, should contact an ET-school and provide necessary information to the school in order to start the selection process. Next, parents would be asked to complete a parental questionnaire and the teacher would be asked to complete a screening questionnaire about the child under consideration. These questionnaires were constructed especially for the ET selection process (Ministry for Education, Science, Youth and Culture of the State Rhineland-Palatinate, 2009). Both questionnaires include a checklist and a set of open questions about behavioral and motivational aspects of the child. The parental questionnaire also includes questions about early cognitive development and asks for proof of extraordinary cognitive performances (e.g., school certifications, rewards and other certificates of performance). It is not explained in the guidelines (Ministry for Education, Science, Youth and Culture of the State Rhineland-Palatinate, 2009) why parents have the opportunity to start the selection process and contribute to the screening, and to what extent educators can trust parents to report on their children’s cognitive development and performance. (2) Based on these screenings, the ET team decides whether the child might be eligible for the program

and if so, sets an appointment for an interview with the parent(s) and the child. The ET team performs a structured interview with the parents and the child during which parents are asked about the child’s interests and social and motivational aspects. During this interview, the child is asked to perform some challenging tasks in the areas of language, mathematics and logical thinking. These tasks require spatial thinking, text comprehension, memory, reasoning, conceptual thinking and number processing skills. Within the interview the number and type of tasks given is attuned to the performance of the child. (3) In a separate meeting, the ET team makes a decision for each child.

### The Present ET Sample

The present study was conducted in a school which in 2009 began participating in the ET program for gifted children in the city of Kaiserslautern (a major city in the German federal state of Rhineland-Palatinate) and neighboring communities. At this particular school, the ET took place Wednesdays, from 8 am to 4 pm. The school provided lunch, drinks, and fruits and vegetables as snacks for all participating children throughout the day. The children were divided into two groups: Group 1, first and second graders, and Group 2, third and fourth graders, i.e., in this ET school, rather than age, the grade level was used as the criterion.

The local implementation and organization of the ET program and the daily schedule followed the guidelines and general rules given by the ministry (for daily schedule see **Table 2**). Every Wednesday the ET class started with children from both groups together with a discussion about the previous week’s work packages, including their feedback on where and with whom they worked on it, and how they liked it. After, there was an open debate on a curriculum-related topic chosen by the teachers or the children.

Thereafter, children were divided into the two groups. In one group, children received lessons in Russian as a foreign language (not offered in traditional schools), while the other worked on the “research projects,” and then vice-versa. The Russian lessons were held by a native speaker in the classic

**TABLE 2 |** Hosted School daily schedule.

Time		Daily Schedule
From	To	
8:00 a.m.	10:00 a.m.	Debate on a topic selected by teachers and/or students and work packages*
10:00 a.m.	11:00 a.m.	Russian lessons
11:00 a.m.	12:00 a.m.	“Own topic”**
12:00 a.m.	13:00 p.m.	Reading and playing
13:00 p.m.	14:00 p.m.	Lunch and exercise (gymnastics)
14:00 p.m.	16:00 p.m.	Experiments

\*Tasks that include reading and writing activities and puzzling and arithmetic problems that ET-children have to work on over the week in their normal classes.

\*\*Each child chooses a topic of interest to research and present to the class. They use internet to perform their research. The presentation is made in poster (Group 1) or power point (Group 2). Each child sets the time limit for their research.

teacher-directed lesson format, with a focus on grammar and translation. In the research projects, using the internet, each child investigated a self-chosen topic of interest, and reported results. Next, there was reading and playing time, in which all children mingled again. At this moment, children had the opportunity to immerse themselves in a book of their choice, or they could play with brain- and strategy games, such as Rush Hour, Chocolate fix, Blokus, or others. After lunch and some sports activities, there was time for scientific experimentation. In this time, with all children present, some experiments were performed with the aim to raise their curiosity and interest in science.

Aside from the weekly activities, there were some excursions such as a hiking/climbing day, a visit to the Technical Museum in Speyer, and to the TECHNOSEUM (State Museum of Technology and Work) in Mannheim, both neighboring cities in Germany.

## Participants

From the hosting primary school, a sample of 190 children from Grade 1 to Grade 4, between the ages of 6 and 10 years old, was tested. The ethical, formal, and legal standards of the study were approved by the *Aufsichts- und Dienstleistungsdirektion Trier (ADD)*, a federal state institution responsible for approving studies conducted in public school). The study was conducted in accordance with the recommendations of The German Society of Psychology after receiving written informed consent from the parents in accordance with the Declaration of Helsinki. Children performed the paper-and-pencil versions of the SPM (Raven, 1998), the CRT (Jaarsveld et al., 2010, 2012), and the TCT-DP (Urban and Jellen, 1995; Form A and B). For all participants, IQ was obtained using the German norms provided for the SPM (1998; 6–18 years old). Participants were divided according to two general cohorts: Intervention group (IG) and control group (CG).

The IG comprised children ( $N = 24$ ,  $M_{\text{age}} = 8.04$ ,  $M_{\text{IQ}} = 133.25$ , 18 male) who participated in the *Entdeckertag (ET)* program. The large control group was composed of children that attended the normal classes in the same primary school where the ET program took place ( $N = 166$ ). From this pool, participants were selected according their gender, grade, IQ, creative reasoning, and creativity scores (on the basis of SPM, CRT, and TCT-DP scores from the first test session, see below) in order to build a matched control group (CG,  $N = 24$ ,  $M_{\text{age}} = 8.00$ ,  $M_{\text{IQ}} = 133$ , 18 male). This means, for each IG child, a control child attending a traditional school class at the same ET school, of the same gender, grade, and close to identical test scores was chosen. Thus, there were 48 participants in total.

## Material

### Standard Progressive Matrices (SPM)

The SPM (Raven, 1998) is a non-verbal intelligence test which measure intelligence the traditional way, i.e., operating in well-defined problem space. The test contains 60 items grouped in five sets; each item comprising an incomplete figure-pattern presented in the form of a  $1 \times 1$ ,  $2 \times 2$ , or  $3 \times 3$  matrix.

Participants are asked to complete the pattern by finding the one correct figure from six or eight possible solution options given below the matrix. The maximum score is 60 points, since each item is fixed as pass or fail. The items are, at first, easy and simple but become increasingly more difficult within and across sets, requiring higher levels of cognitive abilities to encode and analyze information (Raven, 2009). The individual test processing time and the increasing complexity of the SPM items are functional in assessing the extent of clear thinking (Heller et al., 1998).

The SPM was intended to capture the different levels of cognitive ability associated with intelligent performance in as many age groups as possible, regardless of education, nationality, or health condition (Heller et al., 1998). Raven intended to develop a test that would be theoretically relevant, easy to administer, clear to interpret, and could be administered to individuals of different ages and socio-economic backgrounds (Raven, 2009). Normally, the SPM is used from 6 years onward and all candidates have the same set of tasks in the same order (Heller et al., 1998).

### Creative Reasoning Task (CRT)

The CRT is a diagnostic device which measures intelligence and creativity operating intertwined in an ill-defined problem space (in contrast to intelligence tests which measure intelligence the traditional way; operating in well-defined problem space, as SPM; Jaarsveld et al., 2010, 2012). The CRT involves generating components and relations which connect these components, and thus yields a cognitive thinking process in which both intelligent and creative abilities intertwine (Jaarsveld et al., 2015).

In the CRT participants have to conceive a small matrix similar to those found in the SPM. According to the instruction, the matrix must be solvable and as inventive and difficult as possible. For the present study three test forms were applied, each corresponded to one of the three possible types of matrix formats contained in the SPM:  $1 \times 1$ ,  $2 \times 2$ , and  $3 \times 3$ . The figure that completes the matrix should be drawn within the matrix in the outlined square in the lower right corner. Children were free in their choice of test form. The CRT contains two sub-scores: one for intelligence in an ill-defined problem space, i.e., CRT Relations (CRT-R), and one for creativity, i.e., CRT Components & Specifications (CRT-C). Due to research question and design, the latter was not used in the present study.

CRT-R sub-score represents the logic and coherence in a pattern of components for a matrix that was created and it is evaluated by means of defined relations that can deliver up to 128 raw points. These relations are: Matrix  $1 \times 1$  (*Idiosyncratic and Semantic Coherence, Jigsaw, and Pattern Completion*); String (*Iteration of one component, and Iteration of two or >2 components*); Matrix  $2 \times 2$  (*Symmetry, Change, Increase, and Succession*); and Matrix  $3 \times 3$  (*Change, Increase, Succession, Combination, Indication of Mathematical Operation, and Two Values*) (see Jaarsveld et al., 2012 for detailed information). However, as the CRT deals with ill-defined space problems, it is therefore impossible to fix a set of evaluation criteria for all possible solutions.

## Test for Creative Thinking – Drawing Production (TCT-DP)

The TCT-DP (Urban and Jellen, 1995) is a test for the measurement of an individual's creative thinking potential. It can be used to identify very high creative potential as well as to recognize individuals with underdeveloped creative abilities, who may be in need of stimulation and support.

The test contains two answering forms (Form A, and Form B) both providing six figure fragments in a square frame inspiring further drawing. Based on these fragments, the respondent is requested to complete the drawing in a free and open way. Instruction emphasized that one can do nothing wrong. The fragments are: semi-circle, dot, large right angle, curved line, broken line, and a small open square outside the frame.

The drawing is evaluated and scored by means of 14 criteria that can deliver up to six raw points each, except for the four criteria of unconventionality which are valued at a maximum of three points (maximum score = 72). The criteria are: *continuations; completions; new elements; connections made with a line; connections made to produce a theme; boundary breaking that is fragment dependent; boundary breaking that is fragment independent; perspective; humor and affectivity; unconventionality A; unconventionality B; unconventionality C; unconventionality D*, and; *speed*. The test is applicable in single or group testing with individuals aged between 5 and 95 years.

## Procedure

The first test session (T1) took place shortly after the beginning of the school year and the second test (T2) session 36 weeks later, just before the end of the school year. Children were tested in groups within the time frame they would have had their normal classes. They were informed that they could end their participation at any time during the session without the need of reporting any reason. All tests were performed within one session. Children were asked to work quietly and alone. In order to facilitate this, they were seated sufficiently far away from each other. Two researchers conducted the session without the teacher being present. Children were asked firstly to perform the SPM (45 min), then to generate a SPM-style item in the CRT (20 min), and finally to complete the TCT-DP (15 min; Form A first session, Form B second session). The appropriate instruction was given to the whole group before each test. Those children who finished a test before the given time frame were allowed to read books that lay ready to this purpose.

## Data Analyses

Repeated measures ANOVAs controlled for age and *post hoc t*-tests were carried out. When more than one *t*-test was conducted for each dependent variable, multiple testing corrections were used; the *p*-value was then adjusted by the Bonferroni correction. Assumptions for the performed analyses were examined: Shapiro–Wilk test was applied to verify the normality of the sample distribution and the Levene's test to confirm equality of variances between tests. When an assumption was violated, non-parametric statistic tests were additionally performed (namely, Mann–Whitney and Wilcoxon signed-rank tests).

## RESULTS

Means and standard deviations of the SPM, CRT-R, and TCT-DP raw scores of the groups in the two test sessions are presented in **Table 3**.

Regarding SPM, ANOVA showed significant main effect of Group,  $F(1,45) = 6.074$ ,  $p = 0.018$ ,  $\eta_p^2 = 0.674$  and Age,  $F(1,45) = 12.458$ ,  $p = 0.001$ ,  $\eta_p^2 = 0.932$ . Additionally, there was a significant interaction between Time and Group,  $F(1,45) = 4.227$ ,  $p = 0.046$ ,  $\eta_p^2 = 0.521$  (**Figure 1A**). A related *t*-test ( $\alpha = 0.025$ ) revealed that the IG group had a statistically significant improvement from T1 to T2  $t(23) = -3.436$ ,  $p = 0.002$ ; while there was no such effect in the CG [ $t(23) = -0.472$ ,  $p = 0.641$ ]. Furthermore, an independent *t*-test ( $\alpha = 0.025$ ) showed that the IG participants had higher SPM scores than the CG in T2  $t(46) = 2.877$ ,  $p = 0.006$ , whereas there is no such difference evident for T1, for which the samples were matched [ $t(46) = -0.924$ ,  $p = 0.360$ ].

For CRT-R, ANOVA did not show any significant effect, indicating no difference in scores between groups and time (**Figure 1B**). Because the Shapiro–Wilk test demonstrated that the normality of the data distribution cannot be assumed, non-parametric tests were performed additionally. In accordance with ANOVA: (a) The Mann–Whitney test revealed that the IG participants scores in T1 and T2 did not differ significantly from CG participants scores,  $U = 258$ ,  $z = -0.621$ ,  $p = 0.535$  and  $U = 267$ ,  $z = -0.434$ ,  $p = 0.664$ , respectively; and (b) the Wilcoxon signed-rank test showed that there was no significant difference between the participants scores from T1 to T2, neither for IG nor for CG,  $T = 133$ ,  $p = 0.543$  and  $T = 114.25$ ,  $p = 0.072$ , respectively.

Regarding TCT-DP, ANOVA did not show any significant main effect or any interaction (**Figure 1C**).

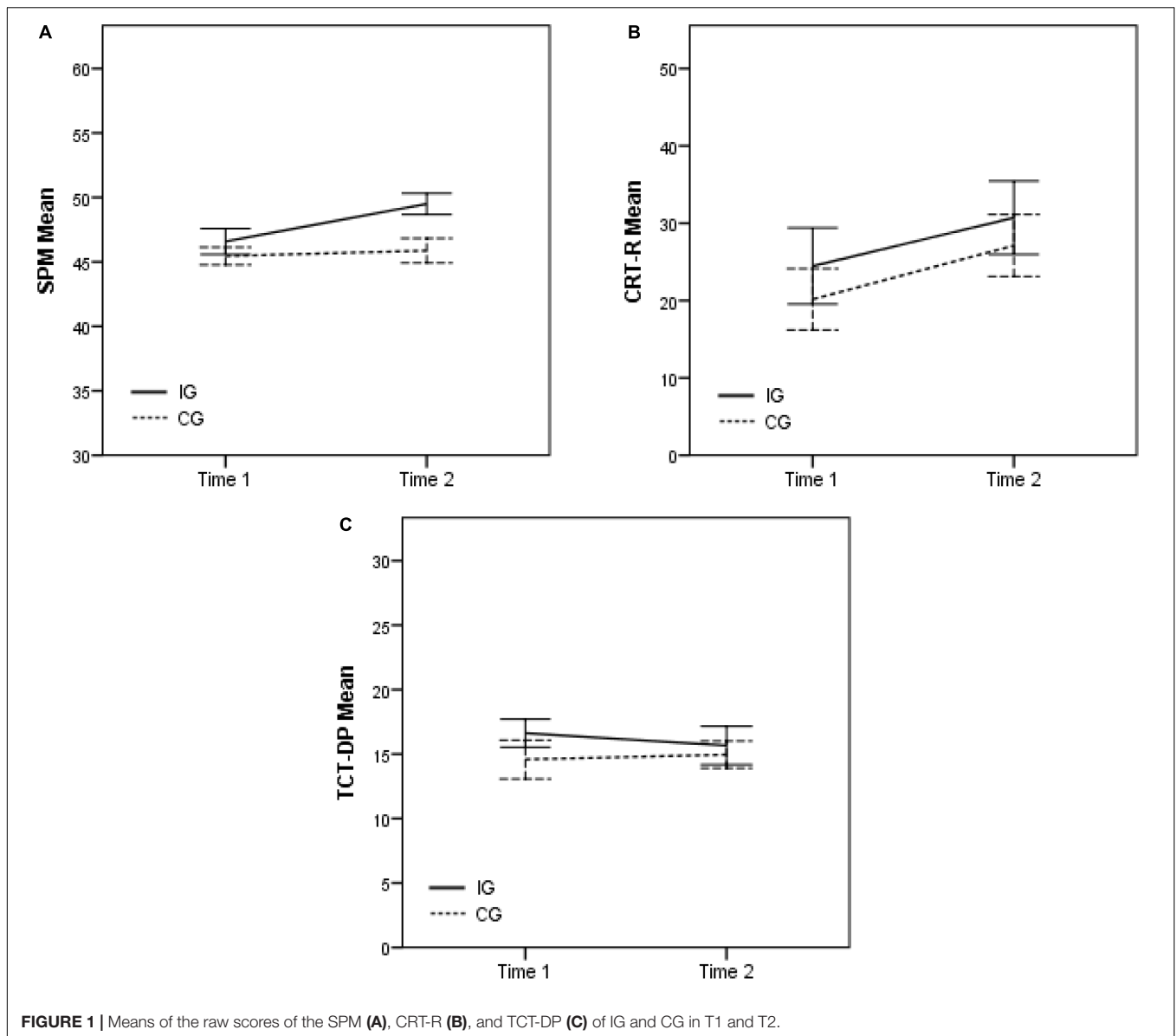
## DISCUSSION

In the present study, we evaluated the effectiveness of an enrichment program for gifted children, the *Entdeckertag Rheinland-Pfalz (ET)*, by comparing performance of primary school children on intelligence and creativity tests over the stretch of one school year. Performance of children who participated

**TABLE 3** | Means and (standard deviations) of raw scores of SPM, CRT-R and TCT-DP of IG and CG in T1 and T2.

Test	IG (N = 24)		CG (N = 24)	
	T1	T2	T1	T2
SPM	46.58 (4.93)	49.50 (4.01)	45.46 (3.35)	45.88 (4.69)
CRT-R	24.46 (24.14)	30.71 (23.27)	20.17 (19.38)	27.13 (19.57)
TCT-DP	16.63 (5.33)	15.67 (7.32)	14.58 (7.38)	14.96 (5.16)

IG group was formed by children that were participating in the *Entdeckertag* program, whereas CG was the control group. SPM, Standard Progressive Matrices; CRT-R, Creative Reasoning Task – Relations sub-score; TCT-DP, Test for Creative Thinking – Drawing Production.



in the ET program was compared against the performance of children who received only normal teaching. These groups were matched on gender, grade and pre-test performance (T1). Children were tested with a standardized intelligence test operating in well-defined problem space (SPM), a standardized creativity test operating in ill-defined problem space (TCT-DP), and an intelligence test that measures intelligence operating in ill-defined problem space (CRT-R).

Results showed that the ET enrichment program has a positive effect on intelligence operating in well-defined problem space, as measured by SPM. ET-children showed an increase in SPM intelligence scores while control children did not. Hence, it seems that, when referring to the traditional concept of intelligence, i.e., intelligence operating in well-defined problem space, the ET program had the appropriate teaching and curriculum to enhance children's performance.

However, this enhancement occurred neither for creativity (TCT-DP) nor for intelligence operating in ill-defined problem space (CRT-R). Results from both of these tests measuring cognitive processes operating in ill-defined problem space showed an identical trend. This is in line with previous findings by Welter et al. (2017), showing that problem space matters. According to which of the two types of problem spaces presented, different cognitive abilities would be elicited from the same child.

According to these authors, in tasks with a well-defined problem space, different abilities are addressed than in tasks with an ill-defined space; intelligence operating in ill-defined space compares better to creativity that also unfolds in ill-defined space than to traditional intelligence. Hence, the present pattern of results together with the findings from Welter et al. (2017) indicate that problem space is an important issue when

interpreting test results. The issue of different problem spaces is the most robust explanation for differences between the results of the two intelligence tests found in the present study, SPM and CRT-R, because both tests use the same knowledge domain.

From this we may infer that the enrichment program was, on the one hand, capable of supporting children in developing cognitive abilities necessary to operate in well-defined problem spaces, but, on the other hand, did not help children to develop their cognitive abilities necessary to operate in ill-defined problem spaces. There are a number of possible explanations for this pattern of effects, including the identification process, the quality and the quantity of the program.

A first explanation could be the fact that the identification method applied for the ET program may have been flawed. In fact, we found that the ET participants were above average in traditional intelligence, most of them with an IQ above 130 for the SPM, but showed a traditional creativity level (TCT-DP) that was average or even below average. This suggests that creative children may have been overlooked (misses), because parents and teachers may be harboring a selection bias that results in considering only children with an above-average school performance. According to Freeman (2005), “teachers often kept a mental image of a gifted pupil who would have exceptionally good logical reasoning abilities, quick comprehension, and intellectual curiosity - in combination with good school grades” (p. 82). To him, highly creative children are generally less agreeable in, and less conforming to, conventional school settings than the ones who are simply highly intelligent. This could be the reason for the former not being selected for giftedness programs. Hany and Heller (1990) found that German teachers did not consider creativity as an indicator of giftedness. They concluded that “teachers want to have the successful and ‘easy to handle’ students in their courses. Critical thinking and having original ideas – signs of creativity – are not ranked highly” (p. 76). Sommer et al. (2008) correlated results obtained in tests of intelligence and creativity with corresponding estimates given by parents and teachers. They observed that parents and teachers could better identify abilities associated with high intelligence than they could detect abilities associated with a high level of creativity. Moreover, it may even be considered possible that parents fabricate information that would enhance their children’s chances of being selected for the program (false alarms).

As a consequence of these identification biases, resulting in both misses and false alarms, many highly intelligent but less creative children were selected for the ET program. The expectation for such a sample would be that a creativity enhancing program would have an even greater effect on the creativity of these children as opposed to children beginning with a high creativity level (Besançon and Lubart, 2008). That there is, however, no effect on creativity in the present study, thus suggests that creative thinking was not challenged sufficiently in the ET program (see below). On the other side, regarding the high IQ level in the present sample, some authors suggested (Sternberg and Kaufman, 2010; Sternberg et al., 2011) that a high level of intelligence may even be an obstacle to the development

of creativity. For a person who is accustomed to viewing things in a certain way, it becomes more and more difficult to consider a different perspective (Sternberg and Kaufman, 2010). According to Sternberg et al. (2011) individuals with a high IQ may find it difficult to think creatively because of their pronounced analytical abilities; “those who have very high IQs may be so highly rewarded for their IQ-like (analytical) skills that they fail to develop their creative potential, which may then remain latent” (p. 88). This fact may also play a role in the threshold phenomenon, which expects no correlation between intelligence and creative abilities above an IQ of 120 (Welter et al., 2016).

The identification process applied for the ET program may also have promoted a gender bias. Note, that in the present study, 75% of the children identified as gifted were boys. According to Gagné (1993), boys and girls are perceived differently by their peers and teachers when it comes to their capability in many domains. Boys are often perceived to be advanced in mathematical and technical skills, requiring more analytical and convergent thinking, and girls are more frequently considered competent in language skills and socio-affective abilities. Since the identification process for the present sample presented children with tasks requiring more analytical and convergent thinking, more boys than girls may have been considered for the ET program.

A second explanation for this pattern of results found in the present study might be the quality of the ET curriculum. It is possible that the ET activities were simply not adequate to support creative thinking. Besides offering the children cognitive activities, in which the task is to search for the one and only correct solution, tasks should be provided for which there is no readily available response.

A third explanation for the present pattern of results may be that the frequency of the ET meetings may have been sufficient to improve intelligence but not sufficient to improve creativity. Since the ET program took place only once a week and in the other days of the week children attended their normal classes, we may infer further that: what little cognitive abilities for operating in ill-defined problem spaces that were developed in the ET program, were not sufficiently sustained further in normal classroom situations. Traditional school teaching encourages traditional intelligence, i.e., those abilities that help cognition to operate in well-defined problem spaces. In contrast, abilities that help cognition to operate in ill-defined problem spaces would thus have less opportunity to be applied in normal school tasks.

Research on the development of intelligence revealed that a child’s intelligence is positively affected by school attendance (e.g., Ceci, 1991; Neisser et al., 1996; Ceci and Williams, 1997). Research on creativity is less consistent. It was found that the educational environment either fosters the development of creativity or incites its decline (e.g., Torrance, 1968; Charles and Runco, 2000; Chae, 2003; Lubart and Georgsdottir, 2004; Maker et al., 2008).

Renzulli and Renzulli (2010) argued that programs destined for gifted education has been a fertile area of experimentation, because these programs are not overwhelmed with prescribed



curriculum guides or traditional educational methods. According to Sternberg et al. (2011) academic skills are undoubtedly important, but they are only part of what leads to the realization of gifted potential. Adjustments made in the ET curriculum, such as increasing the number of activities that foster creative thinking operating in an ill-defined problem space, could be a way to overcome the fact that the traditional schools promote mainly cognitive abilities related to well-defined problem spaces.

Certainly, another approach that would help children to develop their creative potential would be to change the curriculum of the traditional schools. A curriculum which does not promote creative abilities is a worrying educational reality; the lack of opportunities for children to develop creative thinking is troubling (Renzulli and Renzulli, 2010). Creativity has been the common attribute of individuals who have made notable contributions to technological innovations and social improvements (Torrance, 1984). One reason that proves the importance of the enhancement of creative thinking is that “there are challenges within many facets of society to which an immediate or single correct response cannot be found” (Isaksen and Murdock, 1993, p. 16). Educational institutions, therefore, should provide children the opportunities not only to think creatively and to explore the unknown (Torrance, 1972, 1987; Beghetto, 2010; Smith and Smith, 2010), but also to find and formulate problems for which no readily available answer is at hand (Getzels, 1987; Runco, 1994; Carson and Runco, 1999; Kim, 2011). The observations made about creativity in the educational setting are also valid in relation to intelligence measured in ill-defined problem space situations, since the latter compare better to creativity than to intelligence operating in well-defined problem spaces (Welter et al., 2017).

In sum, results of the present evaluation study show the effectiveness of the ET program only in the improvement of intelligence operating in well-defined problem spaces. The outcome that neither ET-children’s creativity scores (TCT-DP) nor their scores of intelligence operating in ill-defined problem spaces (CRT-R) showed an improvement after 1 year of the enrichment program may indicate that problem space is an important issue when interpreting tests results. According to

which of the two types of problem spaces presented, different cognitive abilities would be elicited from the same child.

The present findings might be the consequence of factors which may also interact: the ET identification process, which shows a tendency to choose highly intelligent children with only average creativity, and which promotes more boys than girls; and the quality and quantity of the ET curriculum, which may not have provided enough activities to promote creative thinking and cognitive abilities related to ill-defined problem spaces.

## AUTHOR CONTRIBUTIONS

All authors listed have made substantial, direct, and intellectual contribution to the work, and approved it for publication. TL was the initiator and supervisor of the study; he participated in data analysis and writing, and is the senior as well as the corresponding author. SJ was the co-advisor of the study and participated in data collection, analysis, and writing. MW conducted the study, ran the analyses, and participated in writing. She is the first author; the study is part of her Ph.D. thesis (Welter, 2014), supervised by TL and SJ.

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## REFERENCES

- Baudson, T. G. (2009). “Der rheinland-pfälzische Entdeckertag: Ein Förderprojekt für hochbegabte Grundschüler,” in *Talentförderung Mathematik*, ed. S. Schiemann (Münster: Lit), 379–395.
- Beghetto, R. A. (2010). “Creativity in the classroom,” in *The Cambridge Handbook of Creativity*, eds J. C. Kaufman and R. J. Sternberg (Cambridge: Cambridge University Press), 447–463. doi: 10.1017/CBO9780511763205.027
- Besançon, M., and Lubart, T. (2008). Differences in the development of creative competencies in children schooled in diverse learning environments. *Learn. Individ. Differ.* 18, 381–389. doi: 10.1016/j.lindif.2007.11.009
- Brown, S. W., Renzulli, J. S., Gubbins, E. J., Siegle, D., Zhang, W., and Chen, C.-H. (2005). Assumptions underlying the identification of gifted and talented students. *Gifted Child Q.* 49, 68–79. doi: 10.1177/001698620504900107
- Carson, D. K., and Runco, M. A. (1999). Creative problem solving and problem finding in young adults: interconnections with stress, hassles, and coping abilities. *J. Creat. Behav.* 33, 167–190. doi: 10.1002/j.2162-6057.1999.tb01195.x
- Ceci, S. J. (1991). How much does schooling influence general intelligence and its cognitive components? A reassessment of the evidence. *Dev. Psychol.* 27, 703–722. doi: 10.1037/0012-1649.27.5.703
- Ceci, S. J., and Williams, W. M. (1997). Schooling, intelligence, and income. *Am. Psychol.* 52, 1051–1058. doi: 10.1037/0003-066X.52.10.1051
- Chae, S. (2003). Adaptation of a picture-type creativity test for pre-school children. *Lang. Test.* 20, 178–188. doi: 10.1191/0265532203lt2510a
- Charles, R. E., and Runco, M. (2000). Developmental trends in the evaluative and divergent thinking of children. *Creat. Res. J.* 13, 417–437. doi: 10.1207/S15326934CRJ1334\_19
- Emrich, M., Jost, M., and Noky-Weber, C. (2007). *Begabtenförderung in Rheinland-Pfalz*. Mainz: Ministerium für Bildung.
- Feldhusen, J. F. (2005). “Giftedness, talent, expertise, and creative achievement,” in *Conceptions of Giftedness*, Vol. 2, eds J. E. Davidson and R. J. Sternberg (Cambridge: Cambridge University Press), 64–79.
- Freeman, J. (2005). “Permission to be gifted: how conceptions of giftedness can change lives,” in *Conceptions of Giftedness*, Vol. 2, eds J. E. Davidson and R. J. Sternberg (Cambridge: Cambridge University Press), 80–97.

- Gagné, F. (1993). Sex differences in the aptitudes and talents of children as judged by peers and teachers. *Gifted Child Q.* 37, 69–77. doi: 10.1177/001698629303700204
- Gallagher, J. J. (1988). National agenda for educating gifted students: statement of priorities. *Except. Child.* 55, 107–114. doi: 10.1177/001440298805500202
- Getzels, J. W. (1987). “Creativity, intelligence, and problem finding: retrospect and prospect,” in *Frontiers of Creativity Research: Beyond the Basics*, ed. S. G. Isaksen (Buffalo, NY: Bearly Limited), 88–102.
- Hany, E. A., and Heller, K. A. (1990). “How teachers find their gifted students for enrichment courses –describing, explaining, and improving their selection strategies,” in *The Challenge of Excellence: A Vision Splendid. Selected Papers from the Eighth World Conference on Gifted and Talented Children*, eds S. Bailey, E. Braggett, and M. Robinson (Sidney: Australian Association for the Education of the Gifted and Talented), 71–84.
- Heller, K. A., Kratzmeier, H., and Lengfelder, A. (1998). *Matrizen-Test Manual, Band 1*. Göttingen: Beltz-Test.
- Hunsaker, S. L., and Callahan, C. M. (1993). Evaluation of gifted programs: current practices. *J. Educ. Gifted* 16, 190–200. doi: 10.1177/016235329301600207
- Isaksen, S. G., and Murdock, M. C. (1993). “The emergence of a discipline issues and approaches to the study of creativity,” in *Understanding and Recognizing Creativity: The Emergence of a Discipline*, eds S. G. Isaksen, M. C. Murdock, R. L. Firestien, and D. J. Treffinger (Norwood, NJ: Ablex publ), 13–47.
- Jaarsveld, S., Fink, A., Rinner, M., Schwab, D., Benedek, M., and Lachmann, T. (2015). Intelligence in creative processes: an EEG study. *Intelligence* 49, 171–178. doi: 10.1016/j.intell.2015.01.012
- Jaarsveld, S., and Lachmann, T. (2017). Intelligence and creativity in problem solving: the importance of test features in cognition research. *Front. Psychol.* 8:134. doi: 10.3389/fpsyg.2017.00134
- Jaarsveld, S., Lachmann, T., Hamel, R., and van Leeuwen, C. (2010). Solving and creating Raven Progressive Matrices: reasoning in well- and ill-defined problem spaces. *Creat. Res. J.* 22, 304–319. doi: 10.1080/10400419.2010.503541
- Jaarsveld, S., Lachmann, T., and van Leeuwen, C. (2012). Creative reasoning across developmental levels: convergence and divergence in problem creation. *Intelligence* 40, 172–188. doi: 10.1016/j.intell.2012.01.002
- Kaufman, J. C., Plucker, J. A., and Russel, C. M. (2012). Identifying and assessing creativity as a component of giftedness. *J. Psychoeduc. Assess.* 30, 60–73. doi: 10.1177/0734282911428196
- Kim, K. H. (2011). The creativity crisis: the decrease in creative thinking scores on the Torrance tests of creative thinking. *Creat. Res. J.* 23, 285–295. doi: 10.1080/10400419.2011.627805
- Lubart, T. I., and Georgsdottir, A. (2004). “Creativity: developmental and cross-cultural issues,” in *Creativity: When East Meets West*, eds S. Lau, A. N. Hui, and G. Y. Ng (River Edge, NJ: World Scientific Publishing), 23–54. doi: 10.1142/9789812567192\_0003
- Maker, C. J., Jo, S., and Muammar, O. M. (2008). Development of creativity: the influence of varying levels of implementation of the DISCOVER curriculum model, a non-traditional pedagogical approach. *Learn. Individ. Differ.* 18, 402–417. doi: 10.1016/j.lindif.2008.03.003
- Milgram, R. M. (1990). “Creativity: an idea whose time has come and gone?” in *Theories of Creativity*, Vol. 115, eds M. A. Runco and R. S. Albert (Newbury Park, CA: Sage Publications), 215–233.
- Ministry for Education, Science, Youth and Culture of the State Rhineland-Palatinate (2009). *Hochbegabte Kinder: Erkennen und Fördern Hochbegabter Kinder im Elementar- und Primarbereich*. Mainz: Ministerium für Bildung.
- Ministry for Education, Science, Youth and Culture of the State Rhineland-Palatinate (2011). *Entdeckertag 2004-2011*. Available at: <http://grundschule.bildung-rp.de/projekte/fruehe-hochbegabtenfoerderung/entdeckertag.html>
- Mönks, F. J., and Heller, K. A. (1994). “Identification and programming of the gifted and talented,” in *The International Encyclopedia of Education*, eds T. Husen and T. N. Postlethwaite (Oxford: Pergamon Press), 2725–2732.
- Neisser, U., Boodoo, G., Bouchard, T. J. Jr., Boykin, A. W., Brody, N., et al. (1996). Intelligence: knowns and unknowns. *Am. Psychol.* 51, 77–101. doi: 10.1037/0003-066X.51.2.77
- Newell, A., and Simon, H. A. (1972). “The theory of human problem solving,” in *Human Problem Solving*, eds A. Newell and H. Simon (Englewood Cliffs, NJ: Prentice Hall), 787–868.
- Raven, J. (2009). The raven progressive matrices and measuring aptitude constructs. *Int. J. Educ. Psychol. Assess.* 2, 2–38.
- Raven, J. C. (1998). *Standard Progressive Matrices, Sets A, B, C, D, & E*. Oxford: Oxford Psychologists Press.
- Reis, S. M., and Renzulli, J. S. (2011). “Intellectual giftedness,” in *The Cambridge Handbook of Intelligence*, eds R. J. Sternberg and S. B. Kaufman (Cambridge: Cambridge University Press), 235–252. doi: 10.1017/CBO9780511977244.013
- Renzulli, J. (1982). Dear Mr. and Mrs. Copernicus: we regret to inform you. *Gifted Child Q.* 26, 11–14. doi: 10.1177/001698628202600103
- Renzulli, J. S. (1978). What makes giftedness? Re-examining a definition. *Phi Delta Kappan* 60, 180–184.
- Renzulli, J. S. (2005). “The three-ring conception of giftedness,” in *Conceptions of Giftedness*, Vol. 2, eds J. E. Davidson and R. J. Sternberg (Cambridge: Cambridge University Press), 247–279.
- Renzulli, J. S., and Renzulli, S. R. (2010). The schoolwide enrichment model: a focus on student strengths and interests. *Gifted Educ. Int.* 26, 140–156. doi: 10.1177/026142941002600303
- Robinson, N. M. (2005). “In defense of a psychometric approach to the definition of academic giftedness: a conservative view from a Dei-Hard Liberal,” in *Conceptions of Giftedness*, Vol. 2, eds J. E. Davidson and R. J. Sternberg (Cambridge: Cambridge University Press), 281–294.
- Runco, M. A. (1993). Divergent thinking, creativity, and giftedness. *Gifted Child Q.* 37, 16–22. doi: 10.1177/001698629303700103
- Runco, M. A. (1994). “Conclusions concerning problem finding, problem solving, and creativity,” in *Problem Finding, Problem Solving, and Creativity*, ed. M. A. Runco (Norwood, NJ: Ablex), 272–290.
- Smith, J. K., and Smith, L. F. (2010). “Educational creativity,” in *The Cambridge Handbook of Creativity*, eds J. C. Kaufman and R. J. Sternberg (Cambridge: Cambridge University Press), 250–264. doi: 10.1017/CBO9780511763205.016
- Sommer, U., Fink, A., and Neubauer, A. C. (2008). Detection of high ability children by teachers and parents: psychometric quality of new rating checklists for the assessment of intellectual, creative and social ability. *Psychol. Sci. Q.* 50, 189–205.
- Sternberg, R. J. (1990). What constitutes a “good” definition of giftedness? *J. Educ. Gifted* 14, 96–100. doi: 10.1177/016235329001400110
- Sternberg, R. J. (2005a). “The WICS model of giftedness,” in *Conceptions of Giftedness*, Vol. 2, eds J. E. Davidson and R. J. Sternberg (Cambridge: Cambridge University Press), 327–342. doi: 10.1017/CBO9780511610455.019
- Sternberg, R. J. (2005b). WICS: a model of positive educational leadership comprising wisdom, intelligence, and creativity synthesized. *Educ. Psychol. Rev.* 17, 191–262. doi: 10.1007/s10648-005-5617-2
- Sternberg, R. J. (2010). WICS: a new model for school psychology. *Sch. Psychol. Int.* 31, 599–616. doi: 10.1177/0143034310386534
- Sternberg, R. J., Jarvin, L., and Grigorenko, E. (2011). *Explorations in Giftedness*. Cambridge: Cambridge University Press.
- Sternberg, R. J., and Kaufman, J. C. (2010). “Constraints on creativity: obvious and not so obvious,” in *The Cambridge Handbook of Creativity*, eds J. C. Kaufman and R. J. Sternberg (Cambridge: Cambridge University Press), 467–482. doi: 10.1017/CBO9780511763205.029
- Terman, L. M. (1916). *The Measurement of Intelligence: An Explanation of and a Complete Guide for the Use of the Stanford Revision and Extension for the Binet-Simon Intelligence Scale*. Boston, MA: Houghton Mifflin. doi: 10.1037/10014-000
- Torrance, E. P. (1968). A longitudinal examination of the fourth grade slump in creativity. *Gifted Child Q.* 12, 195–199. doi: 10.1177/001698626801200401
- Torrance, E. P. (1972). Can we teach children to think creatively? *J. Creat. Behav.* 6, 114–143. doi: 10.1002/j.2162-6057.1972.tb00923.x
- Torrance, E. P. (1984). The role of creativity in identification of the gifted and talented. *Gifted Child Q.* 28, 153–156. doi: 10.1177/001698628402800403
- Torrance, E. P. (1987). “Teaching for creativity,” in *Frontiers of Creativity Research: Beyond the Basics*, ed. S. G. Isaksen (Buffalo, N.Y.: Bearly Ltd), 189–215.

- Urban, K. K., and Jellen, H. G. (1995). *Manual - Test zum Schöpferischen Denken - Zeichnerisch (TSD-Z)*. Frankfurt: Swets Test Services.
- Welter, M., Jaarsveld, S., and Lachmann, T. (2017). Problem space matters: the development of creativity and intelligence in primary school children across grade level. *Creat. Res. J.* 29, 1–8. doi: 10.1080/10400419.2017.1302769
- Welter, M., Jaarsveld, S., van Leeuwen, C., and Lachmann, T. (2016). Intelligence and creativity: over the threshold together? *Creat. Res. J.* 28, 212–218. doi: 10.1080/10400419.2016.1162564
- Welter, M. M. (2014). *Creativity, Intelligence and Giftedness: A Study with Primary School Children*. Ph.D. thesis, University of Kaiserslautern, Kaiserslautern.

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# Fostering Children and Adolescents' Creative Thinking in Education. Theoretical Model of Drama Pedagogy Training

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Drama Pedagogy Training (DPT), as other drama-based pedagogies, has been related to several outcomes, including creativity enhancement. This enhancement is commonly proven through the measurement of different creative processes. In our review we systematize characteristics, activities and techniques of DPT that are assumed to be related to creativity in order to have a more comprehensive framework to identify the specific DPT elements that are involved in the enhancement of some of the creative processes of children and adolescents. To this end, we identified five creative processes in experimental studies using DPT: divergent thinking, fantasy and imagination, associative thinking, symbolization, and problem solving. These processes were cross referenced with DPT characteristics, activities, and techniques that were argued to be related to creativity enhancement. Our review will propose a model with two main categories and six elements as follows: (1) *technical drama phases* which emphasizes the role of narrative and embodiment through (a) corporal and vocal training and (b) main drama techniques (e.g., storytelling and improvisation and role-play), and (2) *psycho-pedagogical framework* which emphasizes the role of a dialogic space through (c) playfulness and a (d) collaborative, safe space. We also identified (e) feedback as an important element of DPT which belongs to both drama technical phases and psycho-pedagogical framework categories. Along with the model, we explain the creative outcomes associated to each of these elements as a means to attire the attention to drama-based pedagogies for the development of creativity in the educational setting.

**Keywords:** drama pedagogy, creativity, drama, education, children

## INTRODUCTION

Creativity can be identified in terms of creative thinking through the evaluation of divergent thinking and creative problem solving abilities. These abilities can be enhanced through creativity trainings (Scott et al., 2004), particularly through embodied creativity trainings (Byrge and Tang, 2015) such as drama-based trainings (e.g., Fischer, 1989; Garaigordobil, 2003; Hui and Lau, 2006; Yasar and Aral, 2012; for a review of drama-based trainings: Lee et al., 2015).

A recent meta-analysis conducted by Lee et al. (2015) showed that drama-based trainings (originally presented as Drama-Based Pedagogies) had significant effects on children's creative thinking. Moreover, throughout of the scope of the cited meta-analysis, we found a vast universe of training and pedagogies that are assumed to have an impact on children's creative thinking (e.g., Theater of the oppressed, Boal, 1989; Socio-drama, Moreno, 1943, Drama Pedagogy, García-Huidobro, 1996). Drama Pedagogy Training (DPT), is a particular kind of training issued from Drama Pedagogy García-Huidobro's (1996) that presumes to enhance creative thinking.

The aim of this review is to (a) describe the characteristics of DPT, (b) analyze the specific elements of DPT that should favor creative thinking in children and adolescents, and (c) highlight any specific aspects of creative thinking that are enhanced through these elements of DPT.

For that purpose, we will first describe the conceptual implications of the concept DPT and how it can be found in literature under different names. Secondly, we will briefly review empirical evidence on how DPT or activities issued from DPT enhanced creative thinking. Finally, we will categorize the elements of DPT that might be enhancing creative thinking according to the current literature and organize them in a model for better understanding. This conceptual model will be presented in two main categories (1) Drama Technical Phases which focuses on the practical activities of DPT including (a) corporal expression training and (b) main drama techniques, such as storytelling or improvisation and role-play, and (2) Psycho-Pedagogical Framework which focuses on the characteristics of a DPT session including (c) playfulness, (d) collaborative and safe environment, and (e) feedback.

## DRAMA PEDAGOGY TRAINING (DPT)

In order to understand the concept of DPT, we first need to define Drama Pedagogy. Drama Pedagogy is an active pedagogy based on drama games and techniques. According to García-Huidobro (1996, 2004), it can be divided into four tendencies, namely (a) neoclassical, (b) liberal progressivism, (c) radical, and (d) critical socialism. These tendencies can be inserted in three different areas or dimensions of work, namely (a) inside the educational setting, (b) outside the educational setting, and (c) as a therapeutic dimension. Several combinations of these tendencies and dimensions map onto the concepts reviewed by Lee et al. (2015), even if Drama Pedagogy itself was out of the scope of that study. Thus, DPT can be described as the kind of training that follows the liberal progressivism tendency from Drama Pedagogy inside and outside of the educational setting.

The liberal progressivism tendency of Drama Pedagogy is focused on the experiences that participants can develop through playing drama games rather than preparing a show for an audience (Freeman et al., 2003). In other words, the aim is to contribute to the development of different competencies, such as creativity, by focusing on the process of learning over an artistic result (Heathcote et al., 1991; García-Huidobro, 1996; Woodson, 1999; Libman, 2001; Karakelle, 2009). When Drama Pedagogy is

inserted inside the educational setting through the perspective of the liberal progressivism tendency, it helps the development of integral and creative children<sup>1</sup> (Hui and Lau, 2006; Karakelle, 2009; Cremin and Macdonald, 2013).

In summary, DPT can be considered any training or workshop created through drama activities and techniques (such as pretend play, improvisation, role-play, etc.) that follows the characteristics of the liberal progressivism tendency from Drama Pedagogy. Thus, DPT can be understood as a drama-based training that works with the internal world of the participants (García-Huidobro, 1996) in order to develop creative and socio-emotional competencies, and is focused on the process of learning experiences over artistic or academic results.

For this review, the concept DPT will be used to gather all the training procedures that apply to the characteristics described above, as well as the concepts presented by Freeman et al. (2003) (e.g., child-drama, play-making, child-play, or educational-drama), and the more complex process-oriented methodologies such as socio-drama (Moreno, 1943, 1947; Pecaski, 2012), Creative Drama (Rosenberg, 1981; McCaslin, 1996) or Applied Theatre (Holland, 2009). Overall, this would include all drama-based trainings or pedagogies in which the focus is on the final artistic result or any academic result (e.g., Walker et al., 2011) will not qualify as DPT.

## DPT Improves Creativity: Empirical Evidences

Moreno (1943); Slade (1967), and Boal (1989) can be considered pioneers in DPT as they started the use of dramatic art through representational games in their work with people without searching for any educational nor artistic outcome. Years later, their legacy is still a matter of interest in social sciences, particularly when relating DPT to creativity. In the following section, we will describe the findings of 10 studies relating to creative thinking and DPT in children and adolescents. The analyzed studies correspond to the work of drama-based trainings or pedagogies that match the characteristics of DPT as described above. Some studies have been excluded as the objectives of the training were academic or artistic, or because the particular population presented problems that could lead to a bias, as in the case of children with special needs.

Of all the studies analyzed, only one, conducted in Amato et al. (1973) on 298 school-age children could not prove a significant impact of DPT (originally described by the authors under the name of Creative Dramatics) on children's creative thinking. The researchers looked for significant differences between DPT and other trainings by measuring children's creative thinking through the Torrance Tests of Creative Thinking (TTCT) (Torrance, 1990). According to the authors, storytelling training (which is considered in this papers as an element of DPT) had a higher influence on creative thinking than DPT. Nevertheless, a more detailed methodology from the authors was needed in order to confirm their results. We are not aware of the activities carried on in the different training techniques, so we cannot establish a clear

<sup>1</sup>An integral and creative child should be understood as a child that has developed his/her socio-emotional competencies and creative thinking abilities.

difference between the two mentioned trainings and between the control group and the DPT. The article did not provide the means of each group, so no effect size could be calculated.

Ten years later, Clements et al. (1982) conducted a study on 37 adolescents between 13 and 17 years old in order to evaluate the effects of a DPT program on creativity. Adolescents' creative thinking was measured through the TTCT Demonstrator (Torrance, 1979) and a seven point rating scale was created by two judges in order to measure talent and experience in drama. Results showed significant correlations between TTCT scores and drama experience ( $r = 0.55, p < 0.001$ ) and TTCT scores and drama talent ( $r = 0.46, p < 0.001$ ) suggesting that children with more experience or talent in drama score better in creative thinking tasks. Results provided suggest medium to large effect sizes.

Similarly, Berretta and Privette (1990) studied 184 school-age children in a fourth grade class, looking for a difference between flexible art, drama, and playground activities versus structured art, drama and playground activities. Findings showed that even though there were no significant effects in the type of activity, flexible activities produced significant differences in creative thinking scores on the TTCT (Torrance, 1990) tests versus the structured ones ( $F_{(1,178)} = 4.08, p < 0.05$ ). The effect size of flexible drama and structured drama was analyzed by calculating Cohen's  $d$  based on the mean scores provided by the original article, showing a small effect size ( $D = 0.26$ ). Flexible drama activities, are more related to the concept of playfulness in DPT, where the child is free to construct play following the basic rules of a drama game (McCaslin, 1968).

Authors such as Garaigordobil (1995) have shown that creative drama games, among other cooperative games, enhanced creative thinking (particularly divergent thinking) in a sample of 154 children aged 9–10 years old. Children were assessed using three tasks of the battery of tests Guilford's (1951). Results showed significant differences in the analyses of variance and between the two groups for all three subtests. We calculated Cohen's  $d$  effect sizes on fluidity scores for the three subtests applied, finding large effect sizes for unusual tests ( $D = 1.4$ ) and circle test ( $D = 0.98$ ), and a huge effect size for the consequence test ( $D = 2.8$ ). In 2003 she created different programs (Programa Juego) for children aged from 8 to 12 years old in order to develop creativity and other social competencies such as altruistic behavior through creative drama games and other cooperative games.

A Chinese team, leaded by Hui and Lau (2006) gathered 126 children attending first and fourth grade in order to measure the impact of DPT (originally described under the name of creative drama) on creative thinking. Children participated in an 1-h-a-week DPT, during 16 weeks. They were tested on creative thinking through the Wallach-Kogan Creativity Test (WKCT; Wallach and Kogan, 1965) and the Test of Creative Thinking Drawing Production (TCT-DP; Urban and Jellen, 1996), while also designing a Story Telling Test (STT) to indirectly measure creativity, finding that participants who attended the training generated more creative responses and drawings than the control group. No standard deviation scores were provided for the

WKCT and the TCT-DP tests, so no effect size could be calculated. For the STT, Cohen's  $d$  analysis showed small to medium effect size ( $D = 0.37$ ) on the creativity item.

In a study conducted by Yeh and Li (2008), 116 children aged 4 to 6 years old, participated into a study to see the impact that drama might have on children's creativity. He created the Preschoolers' Creativity Test in order to measure usefulness and novelty indices, finding that the drama training through the different participants age had significant effects on children's creativity with large effect sizes ( $F_{(2,112)} = 42.27, p < 0.001, \eta^2 = 0.43$ ).

Mullineaux and Dilalla (2009) conducted a longitudinal study on 120 children engaged in a 20 min free pretend-play (one fundamental element of DPT). They used a realistic role-play rating to measure pretend-play at age 5, and WKCT Uses-Tasks (Wallach and Kogan, 1965) plus TCT-DP (Urban and Jellen, 1996) to measure creative thinking at age 10–15. Results showed that Realistic-Role-play at age 5 was significantly correlated to WKCT ( $r = 0.18, p < 0.05$ ) and TCT-DP ( $r = 0.22, p < 0.05$ ) scores at follow-up, suggesting that pretend play is predictor of later creative thinking. Results of correlations suggests medium effect sizes.

Lin (2010) studied 67 children aged 11–12 years old engaged in a 10 week intervention two-sessions-a-week DPT. He tested how a drama intervention could enhance possibility thinking, as a facet of creative thinking, through diaries, response sheets and group interviews. Findings showed that children considered the drama training as a useful tool for fostering their creativity. Results from this study are qualitative, so no effect sizes could be calculated.

Garaigordobil and Berruero (2011) in Spain, tested a play based training including drama activities on 86 participants aged 5 and 6. Participants engaged in a 75 min long training sessions each week throughout the academic year. The researchers measured creativity through TTCT and the Escala de Personalidad Creadora (EPC; Garaigordobil and Pérez, 2005) finding that the training significantly increased creative personality traits, as well as verbal (e.g., fluency scores:  $F_{(1,84)} = 39.99$ ) and graphic (e.g., fluency scores:  $F_{(1,84)} = 15.31$ ) creative thinking. They also concluded that was the positive atmosphere what enhanced children's creativity. Cohen's  $d$  were calculated for fluency scores in the TTCT test, showing large to huge effect sizes for verbal ( $D = 1.89$ ) and graphic ( $D = 0.97$ ) tasks.

One year later, Yasar and Aral studied 80 children aged 6 years-old who participated engaged in a twice a week in a drama education workshop over the course of 12 weeks. They were tested through TCT-DP forms A and B showing significant differences between the experimental and the control group ( $t = 16.1, p < 0.000$ ). Besides, we calculated Cohen's  $d$  presenting a huge effect size ( $D = 3.11$ ).

Finally, in, Mottweiler and Taylor (2014) studied the effect of elaborated role play on 75 children aged 4 to 5 years-old. Results showed that children who participated in elaborated role play had higher creativity scores with small to medium effect sizes on narrative ( $F_{(1,68)} = 6.31, p < 0.039, \eta^2 = 0.06$ ) and drawing ( $F_{(1,49)} = 3.08, p = 0.09, \eta^2 = 0.06$ ) creativity tasks.

A recent study, made by Hainselin et al. (2018), showed how improvisational theater helped enhance divergent thinking on 35 adolescents, measured through Alternative Uses Task (AUT; based on Guilford, 1967). Nevertheless, even though improvisation is part of DPT, in their study improvisation is considered as a methodology used for adult actors or adult population, while in our study improvisation is considered as improvisational games within a particular framework (we will detail the framework below). In this line, the study of Hainselin et al. (2018) and other similar works using improvisational theater, should be considered with caution, and only as partial evidence for our study.

Effect sizes are varied for our sample. No mean for effect sizes was calculated, as some effect sizes were calculated via Cohen's *d* and others were provided by ANOVA analyses. Three out of 11 studies, presented problems to find effect sizes or to calculate Cohen's *d*. Eight studies presented sufficient data, and thus effect sizes were calculated. Two out of eight studies presented small or small to medium effect sizes, two out of eight presented medium or medium to large effect sizes and four out of eight presented large, large to huge, or huge effect sizes.

Although the studies described above make a consensus that DPT have an influence on creative thinking, none of these works explained nor differentiated which are the specific elements or characteristics of DPT that are involved in the enhancement of the different facets of creative thinking. Consequently, below we propose a model that aims to explain and categorize the different elements of DPT that are involved in the development of creative thinking.

## DPT MODEL FOR CREATIVE THINKING

According to the literature reviewed above, successful creativity trainings are based on different DPT elements (e.g., Baker, 1996; Freeman et al., 2003). Following this review, we propose to categorize the elements identified into two types of main categories (1) Drama Technical Phases and (2) Psycho-Pedagogical Framework.

The Drama Technical Phases category describes the practical drama-based activities carried out during the DPT training and emphasizes the role of narrative and embodiment through the following elements: (a) corporal expression training (e.g., Byrge and Tang, 2015) and (b) main drama techniques, such as storytelling (Laidlaw, 2000) or improvisation and role-play (e.g., Moreno, 1943; Johnstone, 2012).

The Psycho-Pedagogical Framework category describes the characteristics of a DPT session and emphasizes the role of a dialogic space (including some of the aspects of narrative) through the following elements: (c) playfulness and a (d) collaborative and safe environment.

We also identified (e) feedback as an element of DPT which will be taken as an intersection between drama technical phases and psycho-pedagogical framework categories.

In order to illustrate these findings, please see the proposed model in **Figure 1**.

In the following section we will present each of the previously identified DPT elements discussing their influence on the creativity outcomes and creativity related processes proposed by the current literature.

## The Drama Technical Phases Category

### Corporal Expression Training

Corporal expression training can be understood as the physical training that happens at the beginning of a drama pedagogy session. For instance, participants are asked to move around the space and to explore the different movements they can use to move from one point of the room to another, changing speeds and quality of movements at each time.

The use of the body in support of expression is commonly related to dance. Nevertheless, one fundamental part of dramatic art is the ability to express emotions and thoughts through the body (Snow, 2012). Corporal expression training enables the whole body for being capable to adapt to any situation that might arise (Barba, 1979). Our bodies are the first mediators between the self and the environment because all of our words and emotions go firstly through our bodies before being coded by our brains (Aden, 2014). Consequently, embodiment as a relationship between feelings, ideas, thoughts, behaviors and kinesthetic experiences (Barsalou, 1999), would be the first step to any emotional or cognitive process including creativity, which would develop as a consequence of a particular interaction between the body and its environment. For Martínez and Díaz (2006) motor creativity is the ability to produce fluid, different and novel answers in order to solve a motor function or expression. They explain that when motor tasks are more ambiguous, several cognitive resources work together for the resolution of the task. According to some authors, we can talk of creative task resolution when productions are both novel and adapted to a context (Runco and Jaeger, 2012; Lubart et al., 2015). Further to this, corporal-expression in DPT could also be considered creative if the use of body is original and adapted to the context in which it's being performed. Thus, a movement could be considered *original* if participants express themselves in an uncommon way, while *adaptation* would be related to the ability of the performer to express him/herself accordingly in the space in an *organic/authentic* way. In other words, being able to "fill the empty space" with his/her body in order to clearly transmit ideas or emotions (Brook and Gil Novales, 1997).

Goodwin (1992) suggested that an *authentic movement* creativity is a response that comes from the consciousness of the unity of *body (or experience) with mind (or interpretation)*. When DPTs involve communication between mind and body participants are able to find solutions to conflicts that they would be unable to if this connection was not established (Goff and Torrance, 1991). Creativity is a flux of movement from the unconscious to the conscious body (Halprin, 2014), achieved as a result of the embodiment process. Thus, through corporal expression, we have access to personal information that enables us to create something original and authentic, based on the interrelation of the unconscious and the conscious body. Embodiment is a powerful tool with which to develop creativity

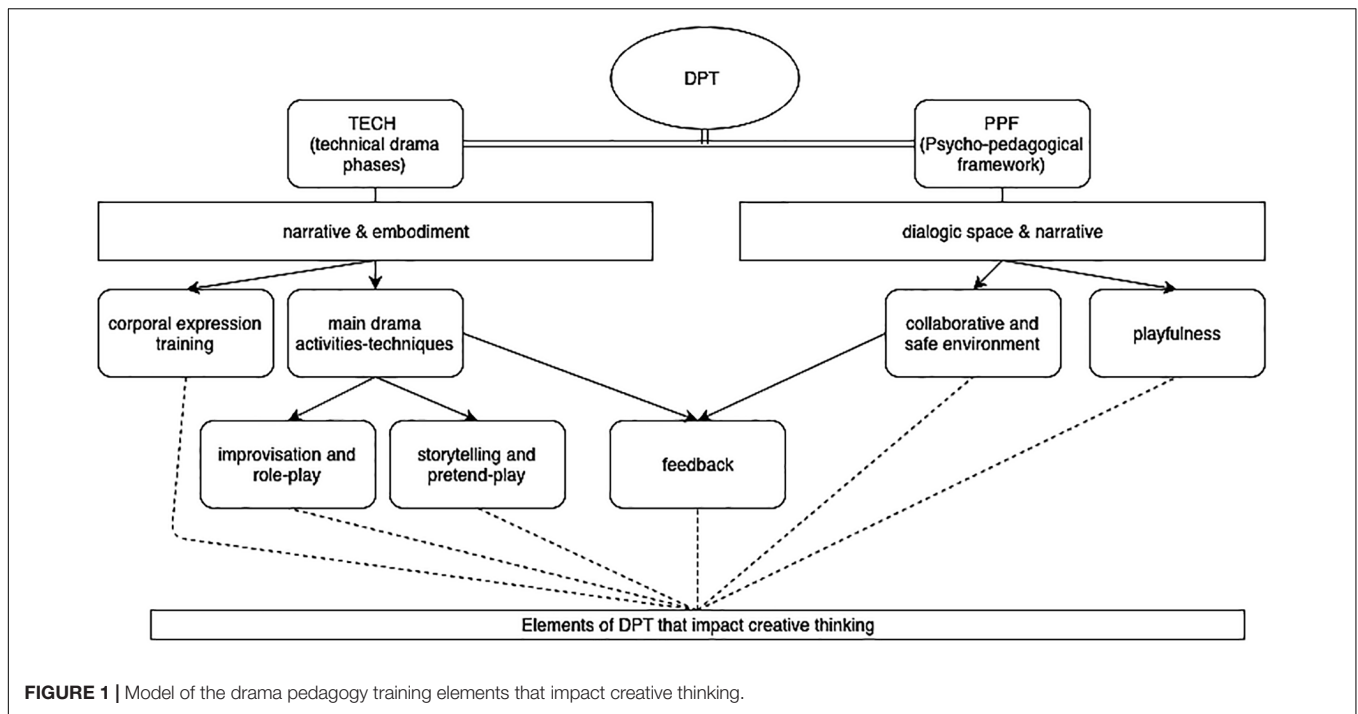


FIGURE 1 | Model of the drama pedagogy training elements that impact creative thinking.

(Byrge and Tang, 2015) as the act of experiencing being someone else leads participants to take risks and explore the unknown (Yaniv, 2012), influencing creativity. Moreover, if we consider creativity from perspective Kharkhurin’s (2014), authenticity is the ability to express the inner self by giving meaning to the creative act, increasing its’ aesthetic value. Authentic movement is a creative process in which ideas are transformed into a creative act by showing the performer’s inner self.

From another perspective, Sofia (2016) proposed that the motor functions of the brain and the motor system are the basis of human thinking, supporting the theory of mirror neurons (Rizzolatti et al., 1996). This demonstrates that creative processes in performers does not result in a creative a piece of art, but explains creativity as an effective relationship with the audience through an adjustment of the body–mind relationship. From this perspective, creativity is achieved through a process of embodiment that results in an empathetic connection between the performer and the audience. Both performer and spectator create a novel and adapted product, transforming reality.

In summary, corporal expression in DPT directly affects creativity through enhancing problem solving abilities, but it also works by developing risk taking and tolerance of the unknown that is achieved through a process of embodiment.

**Main drama techniques: Storytelling and Pretend-Play**

Storytelling and Pretend-Play are both narrative activities (Nicolopoulou, 1997). Pretend play, also called dramatic play (Barbour, 2016) is the ability to narrate a story (Laidlaw, 2000) through enacting narrative scenarios while storytelling uses a discursive exposition of them (Nicolopoulou, 2015). To clarify, storytelling is a way of organizing and telling a story while pretend-play is the enactment of a story. In DPT storytelling is

the moment when participants create their stories and organize them in a way that makes sense to them. Pretend-play in this case, is the way children pretend to use objects that do not exist, and generate actions or sounds, but do not necessarily represent a character (this would be defined as role-play). For example, some children are asked to tell a story (storytelling) while other children create the sounds or represent the activities told within the story (pretend-play).

Several authors associate pretend-play with children’s creativity (e.g., Dansky and Silverman, 1973; Dansky, 1980; Fein, 1981; Singer and Singer, 1990; Urban, 1991; Moore and Russ, 2008; Mullineaux and Dilalla, 2009). Goff and Torrance (1991) have shown that enactment in DPT helped participants to visualize different solutions to a problem fostering their creative, divergent thinking. Similarly, Rosen (1974) and Vandenberg (1980) concluded that through pretend-play children learn about the world enabling them to engage in problem solving creatively. Moreover, Hoffmann and Russ (2012) demonstrated a relationship between storytelling and play, showing that children with greater imagination during play and better organization in their stories (storytelling) were later superior in divergent thinking. They also explain that some cognitive processes related to creativity in pretend-play are divergent thinking and storytelling, highlighting the importance of symbolism and FI abilities. Russ (2004) states that pretend-play allows participants to think of affects and how to express them, enabling children to enhance their ability to connect memories and associations that might help creative problem solving.

Conversely, for Henry (2000) transformation is aided through the creation of metaphors where feeling and imagination interact in order to transmute reality and change the perspective of a situation. Joronen et al. (2011), found that ideas derived



within storytelling increased empathy and perspective, thus impacting creativity. Therefore, in DPT the different points of view and imaginations of participants can change the storytelling of an enacted situation, also enhancing perspective taking and transformation. Mellou (1994) states that transforming the present is a cognitive process related to imagination, and that children's ability to transform objects favors creativity because children are focused beyond the obvious, enabling them to make new associations. Holland (2009) discovered that when children retold their story from different viewpoints to different participants, this helped them to consider different perspectives and create additional, different content. Dramatizing stories directly affects children's motivation and allows them to think in a more sophisticated way (Wright et al., 2008), helping the development of critical thinking and ideation, developing imagination, and divergent thinking.

In summary, during pretend-play creativity is enhanced through the act of performing narrative situations (*enactment*), enabling the development of perspective, divergent thinking, and problem solving. Storytelling, related to organization in play, helps the development of divergent thinking and imagination, while transforming reality helps develop perspective and empathy.

#### **Main drama techniques: Improvisation and Role-Play**

Role-play is a specific kind of pretend-play where a person pretends to be someone else in order to portray a character, while improvisation is related to spontaneous acting. In DPT both activities are used in the form of collective games. On the contrary, in adults' or actors' improvisational theater participants are pushed to showcase. For example, in collective improvisation games, the facilitator may ask participants to create, in a limited amount of time (improvisation), a collective short scene portraying (role-play) someone who is experiencing a particular emotion.

Goff and Torrance (1991) explain that role-play has been used to find solutions to a wide variety of problems and dilemmas, as we can see in Moreno (1943) who explained that role-playing favors participants' capacity to analyze everyday issues. Verriour (1989) describes DPT as a tool based principally on improvisation which develops risk taking, decision making, empathy, and perspective. Role-playing sees participants playing "as-if" they are in the shoes of another. According to McCaslin (1968) playing "as-if" increases mental flexibility, helping individuals to solve challenges or examine issues beyond the obvious, while Dansky (1980) claims that when children engage in "as-if" attitudes it enables them to improve their creative performances, particularly associative fluency. Moreover, Mellou (1995) highlights the work of Sutton-Smith (1967) and Bruner (1972) showing how "as-if" play is directly related to flexibility, inferring that both authors agree that role-play in DPT is a contributor of creative development. This capacity to analyze daily issues by playing "as-if" could help develop problem solving skills, and relates to work on perspective-thinking and empathy, as is proposed by San (2002), Laidlaw (2000); Pecaski (2012) or cited in Erdogan (2013). The latter established that role-playing and improvisation helps participants to reorganize their cognitive patterns when

reviewing experiences, ideas or behaviors within a group. A study by Goldstein and Winner (2012) showed that drama training enhanced empathy through taking in the perspective of different situations that are represented during DPT sessions, by testing a DPT group against music or visual arts. Empathy has been proved to be related to creativity, as creative problem solving depends on the ability to adapt to situations within the environment, and the ability to empathize with situations (Carlozzi et al., 1995).

Hui and Lau (2006) established that role-playing is fundamental in developing creativity, showing that participants in a role-play based DPT carried out greater boundary breaking and elaboration, but also gave more creative responses in standardized tests (WKCT and TCT-DP) than non-participants. Similarly, Burton and Dalby (2012) showed that role-playing radically increased motivation and idea generation, while Karwowski and Soszynski (2008) showed that role-play training increased divergent thinking through fluency scores of their participants.

Furthermore, in a recent study, Sowden et al. (2015) analyzed how dance and drama improvisation activities can enhance divergent thinking in a sample of 27 children aged 7 to 11. For the first experiment, they worked with improvised dance, and in the second with improvised drama. For the improvised drama intervention, children were measured through the figural activity 1 of the TTCT (Torrance, 1974) and it was found that children who took part in the improvisation group showed better divergent thinking after the intervention compared to those in the control group.

In summary, DPT can improve problem solving and divergent thinking abilities in children and adolescents, favored by mental processes that are developed thanks to improvisation and role-play activities, such as boundary breaking, empathy, perspective taking, risk taking and decision making.

## **The Psycho-Pedagogical Framework Category Playfulness**

Drama Pedagogy Trainings are always based on play and improvisation (Yeh and Li, 2008). Since Piaget (1952), authors have had confidence in and proved the importance of play for creativity (e.g., Kneller, 1965; Dansky and Silverman, 1973; Lieberman, 1977; Sutton-Smith, 1979; Christie and Johnsen, 1983; Berretta and Privette, 1990; Mellou, 1995; Garaigordobil and Berruoco, 2011; Hoffmann and Russ, 2012) with only a few studies failing to replicate these effects (e.g., Smith and Whitney, 1987).

Contemporary studies show an increase in children's divergent thinking and associative thinking due to play: Garaigordobil and Berruoco (2011) conducted training throughout the academic year with children aged 5 to 6, demonstrating that there were significant differences in scores ( $F_{(1,84)} = 3.69$ ,  $p < 0.001$ ) on TTCT and Behaviors and Traits of Creative Personality (Garaigordobil, 2006) between play and control groups. Hoffmann and Russ (2012) corroborate these results, concluding that transformation and insight abilities in play are part of creative skills. They worked in a four-session play

intervention with children aged 5 to 10, measuring play through the APS and WKCT-Uses-task. The results showed a positive correlation between divergent thinking and organization in play (fluency  $r = 0.32$ ,  $p < 0.05$ ; flexibility  $r = 0.28$ ,  $p < 0.05$ ), and imagination in play (fluency  $r = 0.38$ ,  $p < 0.05$ ; flexibility  $r = 0.36$ ,  $p < 0.01$ ).

The results described above are in part explained because when playing dramatic games, the child experiments with freedom of expression (Jindal-Snape et al., 2011) and exploration and liberation of the self (Winnicott, 1971) through play, which could help the enhancement of associative thinking (Russ, 2004) and divergent thinking (Russ and Grossman-McKee, 1990).

### Collaborative and Safe Space

Being creative is a participant's decision (Sternberg, 2002), as creativity is affected by the psychological state of participants and their environment (Hohmann and Weikart, 2002). Even though DPT encourages participants to take risks and be creative (Karakelle, 2009), several factors in the creativity environment and space can impact children's mood allowing them to be more or less creative (Morrongiello et al., 2015; Celume et al., 2017). For example, a child's confidence is fundamental in developing a space for free expression (Holland, 2009) which according to Vass et al. (2014) forms part of a co-constructive "interthinking" (Mercer, 2000) in a dialogic and free-of-risks space. This free-of-risk play that DPT space offers enables children to increase their willingness to explore other creative dimensions, due to an enhancement of self-confidence and a lack of fear of being in front of others (Farris and Parke, 1993). Furthermore, the act of observing other participants' performances can impact another participant's awareness of the differing points of view of a situation as well as different solutions to an issue (Karakelle, 2009), thus developing perspective and problem solving abilities.

In a study conducted in Erdogan (2013) showed that children were able to express themselves as a result of the flexible, free learning setting that their teachers had implemented from DPT. A dynamic environment can enhance children's free expression allowing them to be more creative. Jindal-Snape et al. (2011) claim that children's solution finding through a safe environment is not new to DPT as it gives them freedom of expression to find solutions to problems, in a space that permits mistakes. In another study, Garaigordobil and Berruico (2011) mentioned that one element that fostered children's creativity was the positive climate generated in the classroom. Similarly, as mentioned in the pretend play section, having a space in which to experience and express positive effects is important for creativity, and playing collaborative games (like those played in DPT) enhances positive feelings helping construct a positive ambiance that leads children to develop imagination and fantasy (Hoffmann and Russ, 2012). For Vygotsky (1967) children's imagination is developed within child's play as a response to a collaboration between social interactions, allowing learning to occur. The interactions that accompany this process of learning can be observed in the dialogic space of DPT as *intersubjectivities* (Rogoff, 1990), by describing the process of learning that occurs when learners work collaboratively in order to solve a problem.

In summary, a safe space that permits dialogic interactions to occur will favor creativity through the development of

imagination, fantasy, understanding and problem solving abilities as well as by enhancing children's positive mood allowing participants to be more creative.

### Feedback

Feedback occurs at the end of each session. Tam (2016) claims that creative and multiple meaning in DPT might not occur when children are engaged in play, but when they are *back into the real world*. Capron-Pruozzo (2014) explained that if children receive positive feedback regarding their creative personality, their creative self-efficacy will be enhanced. She also claims that if children feel they have the means to face different situations, to take risks, to find solutions and persevere, they will be more engaged in dramatic activities, and vice versa. If participants are motivated they will be open to trying new methods and experience, thus impacting creativity.

Pecaski (2012) claims that all sessions should conclude with an oral discussion to enable children to talk about their personal actions, responses, and feelings on the session. Feedback allows children to think critically about how they acted during the session, and put into perspective how they responded to the presented situation or problem, allowing them to rethink about various appropriate solutions to the original problem. Subsequently, feedback enables children to confront problems presented during the session through dramatic games, motivating them to find novel solutions, thus impacting both perception and problem solving abilities.

## DISCUSSION AND CONCLUSION

The spotting of a structure of DPT, helps to understand and clarify past findings on educational drama studies and to design and conduct future research in order to measure the impact of DPT and its particular elements on children's and adolescents' creative thinking.

Reviews of studies show how different elements of DPT can be related to either creative outcomes or the related processes of the creative thinking. Some studies clearly explain particular creative outcomes, while others present creativity as a whole. **Table 1** presented below intends to summarize the reviewed works in order to present a clearer idea of the relationship between the elements of DPT and the different creative outcomes and creative-related processes.

According to literature reviewed, the majority of creative outcomes measured correspond to Divergent Thinking or are related to Problem Solving, and these can mostly be found within the DPT elements of Storytelling and Pretend-play, and Playfulness. Conversely, the DPT element of Improvisation and Role-Play present more creative related processes, such as risk taking or perspective taking rather than specific creative outcomes. Even though we categorized the elements of DPT in order to link them with creative outcomes, some authors (Goff and Torrance, 1991; Hoffmann and Russ, 2012) relate their results to two or more elements of DPT. In the case of Hoffmann and Russ (2012) they make links between creativity and Pretend-play but also Playfulness, which might imply a connection between the proposed elements.

**TABLE 1** | Elements of DPT and the corresponding creative-related processes and creativity outcomes.

DPT element	Creative-related process (if any)	Creativity outcome referred	Reference
Corporal expression and training	Adaptation to context		Barba, 1979
	Task resolution	Problem solving	Martínez and Díaz, 2006*
		Problem solving	Goff and Torrance, 1991
	Risk Taking + Tolerance of the Unknown		Yaniv, 2012
Storytelling and Pretend-play	Empathy (audience-performer)		Sofia, 2016
	Problem solving	Divergent thinking	Goff and Torrance, 1991
		Problem solving	Rosen, 1974; Vandenberg, 1980
	Fantasy and imagination, symbolism	Divergent thinking	Hoffmann and Russ, 2012
	Think and express affects; associative thinking	Problem solving	Russ, 2004
	Transformation, imagination		Henry, 2000
	Empathy; perspective taking		Joronen et al., 2011
	Transformation, imagination	Associative thinking	Mellou, 1994
	Perspective taking		Holland, 2009
	Critical thinking; ideation	Imagination, divergent thinking	Wright et al., 2008
Improvisation and role-play	Boundary breaking; elaboration; fluency		Hui and Lau, 2006
	Motivation; idea generation		Dalby and Burton, 2013
	Fluency	Divergent thinking	Karwowski and Soszynski, 2008
		Problem solving	Goff and Torrance, 1991
	Risk taking; decision making; empathy; perspective taking		Verriour, 1989
	Flexibility	Problem solving	McCaslin, 1968
	Associative fluency		Dansky, 1980
	Flexibility		Sutton-Smith, 1967; Bruner, 1972 (in Mellou, 1995)
	Perspective taking; empathy	Problem solving	Laidlaw, 2000; Pecaski, 2012
	Empathy; perspective taking		Goldstein and Winner, 2012
Playfulness	Fantasy, imagination	Divergent thinking	Russ, 2003
	Flexibility (activities)	Divergent thinking (originality)	Berretta and Privette, 1990
		Divergent thinking	Garaigordobil and Berruenco, 2011
	Transformation, insight	Divergent thinking	Hoffmann and Russ, 2012
		Associative thinking; symbolization	Russ, 2004
Collaborative and safe space		Divergent thinking	Russ and Grossman-McKee, 1990
	Risk taking		Karakelle, 2009
	Solution finding		Jindal-Snape et al., 2011
	Imagination		Vygotsky, 1967*
Feedback	Creative self-efficacy		Capron-Pruzzo, 2014
	Critical thinking; perspective taking		Pecaski, 2012

\*Some studies are based on theoretical approaches and not DPT empirical studies; They correspond to the specificity of the use of the element in literature (e.g., Martínez and Díaz, 2006 in *Corporal Expression Training*; and Vygotsky, 1967 in *Collaborative and Safe Space*).

Goff and Torrance (1991) observed that creativity was enhanced as part of Corporal Expression Training, Storytelling and Pretend-play, and Improvisation and Role-play, without always specifying the role of each element. For this reason, even though we categorized different elements of DPT in order to clarify which specific elements impact creative processes, it seems equivocal to establish that only one element by itself is responsible for the enhancement of creativity.

The proposed synthesis and model are based in diverse literature, meaning that even if the cited literature showed positive effects of DPT on creativity, there are limitations. These limitations should be taken into account before citing any generalizations of the effectiveness of this model.

The biggest limitations are, in one part, a lack of well-designed protocols in certain studies that made it impossible

to include many of them in the review. This is a common issue in drama-based literature, as most studies do not present complete reports, often missing critical analysis of results and deeper statistical analyses. This subsequently makes it difficult to predict the effects of specific elements of training beyond the authors' interpretations, and replication possibilities are therefore limited.

Consequently, we propose to be very specific regarding the description of protocols, citing the duration of the intervention: "how many hours did the intervention last?," "how many times a week did it occur?," "for how long?" while also being specific about the activities carried on as part of the training: "how was the training constructed?," "which type of activity was carried out first?," "which one was carried out last?," "did every session have the same structure?," or "which elements of DPT were present

during the intervention?” Furthermore, we propose to describe the variables that were measured and the instruments that were used to measure those variables. Within the literature reviewed, we had to dismiss interesting studies owing to the fact that the variables weren't clear. For example, creativity or empathy development is referred to without defining the terms or the instruments used to measure them. It is also established that DPT had an impact on creativity, but without being specific on how creativity was measured. How Instruments were constructed or their validity is not fully explained, and results are reported vaguely without specifying effect sizes, correlations or even the significance of results. Consequently, more detailed descriptions of variables and results are also required.

In this line, the categorization of the elements of DPT helps us understand what are the specific creative outcomes that have been developed (or could be developed) through a particular element of DPT or through an ensemble DPT. Nevertheless, not all the studies reviewed offer a detailed description of the activities and elements of each session, making it difficult to establish whether one of the elements of DPT was not present in the training where creative outcomes were measured. Future research in the area should consider providing a more complete description of the approach, explicitly stating the final objective of the proposed training. A description of the different types of activities or elements used could also be important information that could be used to corroborate or update the proposed model, with the aim of contributing to the understanding of the process of creative thinking through DPT. With this kind of structure complementing by observations, impressions and theories of researchers and artists, we may develop more holistic, concrete and valid proofs to ensure the positive impact of DPT and its elements on children's development.

Following this lead, even though this review presented evidence based on experimentation, some elements of DPT are related to perspectives that go beyond the scope of statistical findings. In other words, these kind of pedagogies and works based on dramatic art, demonstrate that scientific evidence could benefit from arts and humanities for complementing results, as happened with the case of Kharkhurin's (2014) concept of creativity described for understanding creative outcomes through the corporal expression element of DPT. A more anthropological perspective of drama would explain creative thinking through symbolization and transformation abilities, by the transformation of social interrelations into symbolic representations of reality. In other words, social drama would impact creativity through a ritualistic metaphorical representation of social communities (Turner, 1975; Tydeman, 1988). For example, pretense is the metaphor of reality. Some studies have related metaphors to creativity related outcomes,

as innovative thinking (Holstein, 1972) as well as metaphor, seen as the capacity of transforming reality by “existing” in both a fantasy and a real world (Bolton, 1979) is given thanks to DPT. In summary, sociological or anthropological perspectives of creativity and drama give us vast possibilities of discussion that could be used to complement quantitative analyses in future work.

On the other hand, The size of our sample seems insufficient for drawing further conclusions, as the majority of drama-based pedagogies' literature corresponds to trainings focused on academic outcomes, like those included in the meta-analysis of Lee et al. (2015), and not DPT or creative drama trainings. Thus, we assume a possible involuntary exclusion of pertinent studies.

In any case, the vast majority of the studies showed that a drama-based pedagogy following the approach of DPT, develops creative thinking and creativity related processes in children. From our perspective, these findings have implications principally for school teachers and drama pedagogies, as well as for different professionals and actors in the educational and psycho-educational fields. We suggest further investigation of the elements of DPT that enhance creative thinking and a more thorough report of the studies carried out. Therefore, we believe that drama-pedagogy studies could benefit from an interdisciplinary approach in order to conduct studies that could gather the experience of artists and educators, but at the same time also report results and analysis of DPT practices in a more scientific way. This could benefit not only scientific research in the creativity field, but will also be beneficial for artists who want to understand the implications of dramatic art for the development of creativity, as well as for educators who are willing to develop the creative skills of children and adolescents in their classrooms.

## AUTHOR CONTRIBUTIONS

M-PC wrote the manuscript and with support of MB and FZ. FZ coordinated and supervised the research review. All authors provided critical feedback and helped to shape the analyses and manuscript.

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## REFERENCES

- Aden, J. (2014). Empathie et pratiques théâtrales en didactique des langues. *E-CRINI* 6, 1–8.
- Amato, A., Ziegler, E., and Emans, R. (1973). The effectiveness of creative dramatics and storytelling in a library setting. *J. Educ. Res.* 67, 161–162. doi: 10.1080/00220671.1973.10884592
- Baker, B. R. (1996). *Drama and Young Children*. Waco, TX: School of Education, Baylor University.
- Barba, E. (1979). *The Floating Islands*, ed. F. Taviani (Holstebro: Thomsens Bogtrykkeri).
- Barbour, A. (2016). *Essentials for Learning: Encouraging Dramatic Play and Creative Expression in Early Childhood*. Princeton, NJ: Early Learning Book.

- Barsalou, L. (1999). Perceptions of perceptual symbols. *Behav. Brain Sci.* 22, 637–660. doi: 10.1017/S0140525X99532147
- Berretta, S., and Privette, G. (1990). Influence of play on creative thinking. *Percept. Mot. Skills* 71, 659–666. doi: 10.2466/pms.1990.71.2.659
- Boal, A. (1989). *Juegos Para Actores y no Actores*. Caracas: Alba.
- Bolton, G. (1979). *Towards and Theory of Drama in Education*. London: Longmans.
- Brook, P., and Gil Novales, R. (1997). *El Espacio Vacío: Arte y técnica del Teatro*. Barcelona: Peninsula
- Bruner, J. (1972). Nature and uses of immaturity. *Am. Psychol.* 27, 687–708. doi: 10.1037/h0033144
- Burton, S., and Dalby, J. (2012). Psychological autopsy in the investigation of serial neonaticides. *J. Forensic Sci.* 57, 270–272. doi: 10.1111/j.1556-4029.2011.01934.x
- Byrge, C., and Tang, C. (2015). Embodied creativity training: effects on creative self-efficacy and creative production. *Think. Skills Creat.* 16, 51–61. doi: 10.1016/j.tsc.2015.01.002
- Capron-Pruzzo, I. (2014). Pédagogie de la créativité, activités théâtrales et auto-efficacité créative. *Lang. Mod.* 4, 48–57.
- Carlozzi, A., Bull, K., Eells, G., and Hurlburt, J. (1995). Empathy as related to creativity, dogmatism, and expressiveness. *J. Psychol. Interdiscip. Appl.* 129, 365–373. doi: 10.1080/00223980.1995.9914974
- Celume, M.-P., Sovet, L., Lubart, T., and Zenasni, F. (2017). “The relationship between children’s creativity and well-being at school,” in *Creativity, Innovation and Wellbeing*, eds En M.-P. Celume, L. Sovet, T. Lubart, F. Zenasni, and F. K. Reisman (London: KIE Conference Publications), 346–362.
- Christie, J., and Johnsen, E. (1983). The role of play in social-intellectual development. *Rev. Educ. Res.* 53, 93–115. doi: 10.1097/MOP.0000000000000550
- Clements, R., Dwinell, P., Torrance, E., and Kidd, J. (1982). Evaluation of some of the effects of a teen drama program on creativity. *J. Creat. Behav.* 16, 272–276. doi: 10.1002/j.2162-6057.1982.tb00342.x
- Cremin, T., and Macdonald, R. (2013). “Developing creativity through drama,” in *Creativity in the Primary Curriculum*, eds T. Cremin, R. Macdonald, R. Jones, and D. Wyse (Abingdon: Routledge), 83–97.
- Dalby, M., and Burton, N. (2013). What is the impact on six underachieving year 4 children’s choice of language and development of character when ‘writing in role’? *Education* 3–13, 82–89.
- Dansky, J. (1980). Make-believe: a mediator of the relationship between play and associative fluency. *Child Dev.* 51, 576–579. doi: 10.2307/1129296
- Dansky, J., and Silverman, I. (1973). Effects of play on associative fluency in preschool-aged children. *Dev. Psychol.* 9, 38–43. doi: 10.1037/h0035076
- Erdogan, T. (2013). The effect of creative drama method on pre-service classroom teachers’ writing skills and attitudes towards writing. *Aust. J. Teach. Educ.* 38, 45–61. doi: 10.14221/ajte.2013v38n1.5
- Farris, P., and Parke, J. (1993). To be or not to be: what students think about drama. *Clear. House* 4, 231–234. doi: 10.1080/00098655.1993.9955979
- Fein, G. (1981). Pretend play in childhood: an integrative review. *Child Dev.* 52, 1095–1118. doi: 10.2307/1129497
- Fischer, C. (1989). *Effects of a Development Drama-inquiry Process on Creative and Critical Thinking Skills in Early Adolescent Students*. Manhattan, KS: Kansas State University.
- Freeman, G., Sullivan, K., and Fulton, C. (2003). Effects of creative drama on self-concept, social skills, and problem behavior. *J. Educ. Res.* 96, 131–138. doi: 10.1080/00220670309598801
- Garaigordobil, M. (1995). Intervención en la creatividad: evaluación de una experiencia. *Rev. Iberoam. Diagn. Eval. Psicol.* 1, 37–62.
- Garaigordobil, M. (2003). *Programa Juego. Juegos Cooperativos y Creativos Para Grupos de niños de 8 a 10 años*. Madrid: Ediciones Pirámide.
- Garaigordobil, M. (2006). “EPC escala de personalidad creadora: evaluación de conductas y rasgos de la personalidad creativa infantil,” in *Comprender y Evaluar la Creatividad*, eds M. Garaigordobil and S. Verónica Violant (Málaga: Ediciones Aljibe), 324–332.
- Garaigordobil, M., and Berruero, L. (2011). Effects of a play program on creative thinking of preschool children. *Spanish J. Psychol.* 14, 608–618. doi: 10.5209/rev\_SJOP.2011.v14.n2.9
- Garaigordobil, M., and Pérez, J.-I. (2005). Escala de personalidad creadora: estudio psicométrico exploratorio. *Estud. Psicol.* 26, 345–364. doi: 10.1174/021093905774519026
- García-Huidobro, V. (1996). *Manual de Pedagogía Teatral*. Santiago: Los Andes.
- García-Huidobro, V. (2004). *Pedagogía Teatral. Una Metodología Activa en el Aula*. Santiago: Pontificia Universidad Católica de Chile.
- Goff, K., and Torrance, E. (1991). Healing qualities of imagery and creativity. *J. Creat. Behav.* 25, 296–303. doi: 10.1002/j.2162-6057.1991.tb01141.x
- Goldstein, T., and Winner, E. (2012). Enhancing empathy and theory of mind. *J. Cogn. Dev.* 13, 19–37. doi: 10.1080/15248372.2011.573514
- Goodwin, A. (1992). Authentic movement: from embryonic curl to creative thrust. *J. Creat. Behav.* 26, 273–281. doi: 10.1002/j.2162-6057.1992.tb01187.x
- Guilford, J. (1951). *Guilford Test for Creativity*. Beverly Hills: Sheridan Supply Company.
- Guilford, J. (1967). *The Nature of Human Intelligence*. New York, NY: McGraw-Hill.
- Hainselin, M., Aubry, A., and Bourdin, B. (2018). Improving teenagers’ divergent thinking with improvisational theater. *Front. Psychol.* 9:1759. doi: 10.3389/fpsyg.2018.01759
- Halprin, D. (2014). *La Force Expressive du Corps*. Gap: Le Souffle d’or.
- Heathcote, D., Johnson, L., and O’Neill, C. (1991). *Dorothy Heathcote: Collected Writings on Education and Drama*. Evanston, IL: Northwestern University Press.
- Henry, M. (2000). Drama’s ways of learning. *Res. Drama Educ. J. Appl. Theatre Perform.* 5, 45–62. doi: 10.1080/135697800114195
- Hoffmann, J., and Russ, S. (2012). Pretend play, creativity, and emotion regulation in children. *Psychol. Aesthet. Creat. Arts* 6, 175–184. doi: 10.1037/a0026299
- Hohmann, M., and Weikart, D. (2002). *Educating Young Children*, 2 Edn. Ypsilanti: High/Scope Press.
- Holland, C. (2009). Reading and acting in the world: conversations about empathy. *J. Appl. Theatre Perform.* 14, 529–544. doi: 10.1080/13569780903286030
- Holstein, B. (1972). Use of metaphor to induce innovative thinking in fourth grade children. *Education* 1, 56–60.
- Hui, A., and Lau, S. (2006). Drama education: a touch of the creative mind and communicative-expressive ability of elementary school children in Hong Kong. *Think. Skills Creat.* 1, 34–40. doi: 10.1016/j.tsc.2005.06.001
- Jindal-Snape, D., Vetraino, E., Lowson, A., and McDuff, W. (2011). Using creative drama to facilitate primary-secondary transition. *Education* 3–13, 383–394. doi: 10.1080/03004271003727531
- Johnstone, K. (2012). *Impro: Improvisation and the Theatre*. London: Routledge. doi: 10.4324/9780203446294
- Joronen, K., Håkämies, A., and Åstedt-Kurki, P. (2011). Children’s experiences of a drama programme in social and emotional learning. *Scand. J. Caring Sci.* 25, 671–678. doi: 10.1111/j.1471-6712.2011.00877.x
- Karakelle, S. (2009). Enhancing fluent and flexible thinking through the creative drama process. *Think. Skills Creat.* 4, 124–129. doi: 10.1016/j.tsc.2009.05.002
- Karwowski, M., and Soszynski, M. (2008). How to develop creative imagination?. Assumptions, aims and effectiveness of role play training in creativity (RPTC). *Think. Skills Creat.* 3, 163–171. doi: 10.1016/j.tsc.2008.07.001
- Kharkhurin, A. (2014). Creativity.4in1: four-criterion construct of creativity. *Creat. Res. J.* 26, 338–352. doi: 10.1080/10400419.2014.929424
- Kneller, G. (1965). Education as a discipline. *Stud. Philos. Educ.* 4, 136–156. doi: 10.1007/BF00373954
- Laidlaw, L. (2000). Educational drama and language arts: what research shows (book review). *Educ. Stud.* 3, 296–299.
- Lee, B., Patall, E., Cawthon, S., and Steingut, R. (2015). The effect of drama-based pedagogy on preK-16 outcomes: a meta-analysis of research from 1985 to 2012. *Rev. Educ. Res.* 85, 3–49. doi: 10.3102/0034654314540477
- Libman, K. (2001). What’s in a name? an exploration of the origins and implications of the terms creative dramatics and creative drama in the United States: 1950s to the present. *Youth Theatre J.* 15, 23–32. doi: 10.1080/08929092.2001.10012528
- Lieberman, J. (1977). *Playfulness: Its Relationship to Imagination and Creativity*. London: Academic Press.
- Lin, Y. (2010). Drama and possibility thinking - taiwanese pupils’ perspectives regarding creative pedagogy in drama. *Think. Skills Creat.* 5, 108–119. doi: 10.1016/j.tsc.2010.09.001
- Lubart, T., Mouchiroud, C., Tordjman, S., and Zenasni, F. (2015). *Psychologie de la Créativité*. 2nd Edn. Paris: Armand Colin.
- Martínez, A., and Díaz, M. (2006). Eficacia de un programa de intervención para la mejora de la creatividad motriz en un grupo de discapacitados psíquicos. *Apuntes Educ. Física Deporte.* 84, 13–21.
- McCaslin, N. (1968). *Creative Dramatics in the Classroom*, 2 Edn. New York, NY: McKay.

- McCaslin, N. (1996). *Creative Drama in the Classroom and Beyond*, 6th Edn. White Plains, NY: Longman.
- Mellou, E. (1994). The values of dramatic play in children. *Early Child Dev. Care* 104, 105–114. doi: 10.1080/0300443941040109
- Mellou, E. (1995). Relationship between dramatic play and creativity in young children. *Early Child Dev. Care* 112, 85–107. doi: 10.1080/0300443951120108
- Mercer, N. (2000). *Words and Minds: How We Use Language to Think Together*. London: Routledge.
- Moore, M., and Russ, S. (2008). Follow-up of a pretend play intervention: effects on play, creativity, and emotional processes in children. *Creat. Res. J.* 20, 427–436. doi: 10.1080/10400410802391892
- Moreno, J. (1943). Sociometry and the cultural order. *Sociometry* 6, 299–344. doi: 10.2307/2785184
- Moreno, J. (1947). *The Theatre of Spontaneity*. New York, NY: Beacon House.
- Morrongio, B., Stewart, J., Pope, K., Pogrebtsova, E., and Boulay, K.-J. (2015). Exploring relations between positive mood state and school-age children's risk taking. *J. Pediatr. Psychol.* 40, 406–418. doi: 10.1093/jpepsy/jsu100
- Mottweiler, C., and Taylor, M. (2014). Elaborated role play and creativity in preschool age children. *Psychol. Aesthet. Creat. Arts* 8, 277–286. doi: 10.1037/a0036083
- Mullineaux, P., and Dilalla, L. (2009). Preschool pretend play behaviors and early fiddlestick creativity. *J. Creat. Behav.* 43, 41–57
- Nicolopoulou, A. (1997). "Children and narratives: toward an interpretive and sociocultural approach," in *Narrative Development: Six Approaches*, eds A. Nicolopoulou, M. G. W. Bamberg, and N. Mahwah (Mahwah, NJ: Lawrence Erlbaum Associates Publishers).
- Nicolopoulou, A. (2015). "Young children's pretend play and storytelling as modes of narrative activity: from complementarity to cross-fertilization?," in *Children's Play, Pretense, and Story: Studies in Culture, Context, and Autism Spectrum Disorder*, ed. A. Nicolopoulou (Abingdon: Routledge).
- Pecaski, M. D. (2012). Using sociodrama to help young children problem solve. *Early Child. Educ. J.* 39, 407–412. doi: 10.1007/s10643-011-0482-9
- Piaget, J. (1952). *Play, Dreams and Imitation in Childhood*. New York, NY: W W Norton & Co.
- Rizzolatti, G., Fadiga, L., Gallese, V., and Fogassi, L. (1996). Premotor cortex and the recognition of motor actions. *Cogn. Brain Res.* 3, 131–141. doi: 10.1016/0926-6410(95)00038-0
- Rogoff, B. (1990). *Apprenticeship in Thinking: Cognitive Development in Social Context*. Oxford: Oxford University.
- Rosen, C. (1974). The effects of sociodramatic play on problem-solving behavior among culturally disadvantaged preschool children. *Child Dev.* 45, 920–927. doi: 10.2307/1128077
- Rosenberg, H. (1981). Drama in schools: it's theory and practice (book review). *J. Teach. Educ.* 32:47. doi: 10.1177/002248718103200112
- Runco, M., and Jaeger, G. (2012). The standard definition of creativity. *Creat. Res. J.* 24, 92–96. doi: 10.1080/10400419.2012.650092
- Russ, S. (2003). Play and creativity: developmental issues. *Scand. J. Educ. Res.* 47, 291–303. doi: 10.1080/00313830308594
- Russ, S. (2004). *Play in Child Development and Psychotherapy: Toward Empirically Supported Practice*. Mahwah, NJ: Erlbaum Associate Publishers.
- Russ, S., and Grossman-McKee, A. (1990). Affective expression in children's fantasy play, primary process thinking on the rorschach, and divergent thinking. *J. Pers. Assess.* 54, 756–771. doi: 10.1080/00223891.1990.9674036
- Scott, G., Leritz, L., and Mumford, M. (2004). The effectiveness of creativity training: a quantitative review. *Creat. Res. J.* 16, 361–388. doi: 10.1080/10400410409534549
- Singer, D., and Singer, J. (1990). "Cognitive and emotional growth through play," in *The House of Make-Believe: Children's Play and the Developing Imagination*, eds D. Singer and J. Singer (Cambridge, MA: Harvard University Press).
- Slade, P. (1967). "Child drama and its value in education in," in *Proceedings of the 1st Drama Conference of the Department of Education and Science for Wales, Bangor University*, (Bromley: Stacey Publications), 22.
- Smith, P., and Whitney, S. (1987). Play and associative fluency: experimenter effects may be responsible for previous positive findings. *Dev. Psychol.* 23, 49–53. doi: 10.1037/0012-1649.23.1.49
- Snow, J. (2012). *Movement Training for Actors*. London: Bloomsbury. doi: 10.5040/9781408189429
- Sofia, G. (2016). "Embodied creativity. formation de l'acteur et neurosciences de la créativité," in *La Créativité en Éducation et Formation*, eds G. Sofia and I. C. Pruzzo (Louvain: De Boeck Supérieur).
- Sowden, P., Clements, L., Redlich, C., and Lewis, C. (2015). Improvisation facilitates divergent thinking and creativity: realizing a benefit of primary school arts education. *Psychol. Aesthet. Creat. Arts* 9, 128–138. doi: 10.1037/aca0000018
- Sternberg, R. (2002). Creativity as a decision. *Am. Psychol.* 57:376. doi: 10.1037/0003-066X.57.5.376a
- Sutton-Smith, B. (1967). The role of play in cognitive development. *Young Child.* 22, 360–370.
- Sutton-Smith, B. (1979). *Play and Learning*. New York, NY: Gardner Press.
- Tam, P. (2016). Children's creative understanding of drama education: a bakhtinian perspective. *Think. Skills Creat.* 20, 29–39. doi: 10.1016/j.tsc.2016.02.003
- Torrance, E. (1974). *Torrance Tests of Creative Thinking. Directions Manual and Scoring Guide Verbal Test Booklet*. Bensenville: Scholastic Testing Services.
- Torrance, E. (1979). *The Search for Satori and Creativity*. New York, NY: Creative Educational Foundation.
- Torrance, E. (1990). *The Torrance Test of Creative Thinking*. Bensenville: Scholastic Testing Service.
- Turner, V. (1975). *Dramas, Fields, and Metaphors: Symbolic Action in Human Society*. Ithaca: Cornell University Press.
- Tydemann, W. (1988). "Drama and Ritual in Murder," in *The Cathedral and The Cocktail Party*, ed. W. Tydemann (London: Macmillan Education). doi: 10.1007/978-1-349-08937-6
- Urban, K. (1991). On the development of creativity in children. *Creat. Res. J.* 4, 177–191. doi: 10.1080/10400419109534384
- Urban, K., and Jellen, G. (1996). *Test for Creative Thinking- Drawing Production*. Lisse: Swets and Zeitlinger.
- Vandenberg, B. (1980). Play, problem-solving, and creativity. *New Dir. Child Adolesc. Dev.* 1980, 49–68. doi: 10.1002/cd.23219800906
- Vass, E., Littleton, K., Jones, A., and Miell, D. (2014). The affectively constituted dimensions of creative interthinking. *Int. J. Educ. Res.* 66, 63–77. doi: 10.1016/j.ijer.2014.02.004
- Verriour, P. (1989). This is drama. *Lang. Arts* 65, 284–286.
- Vygotsky, L. (1967). Play and its role in the mental development of the child. *Sov. Psychol.* 5, 6–18. doi: 10.2753/RPO1061-040505036
- Walker, E., Tabone, C., and Weltsek, G. (2011). When achievement data meet drama and arts integration. *Lang. Arts* 88, 365–372.
- Wallach, M., and Kogan, N. (1965). A new look at the creativity-intelligence distinction. *J. Pers.* 33, 348–369. doi: 10.1111/j.1467-6494.1965.tb01391.x
- Winnicott, D. (1971). *The Child, the Family and the Outside World*. London: Penguin Books.
- Woodson, S. (1999). (Re) Conceiving 'creative drama': an exploration and expansion of american metaphorical paradigms. *Res. Drama Educ.* 4, 201–214. doi: 10.1080/1356978990040204
- Wright, C., Bacigalupa, C., Black, T., and Burton, M. (2008). Windows into children's thinking: a guide to storytelling and dramatization. *Early Childh. Educ. J.* 35, 363–369. doi: 10.1007/s10643-007-0189-0
- Yaniv, D. (2012). Dynamics of creativity and empathy in role reversal: contributions from neuroscience. *Rev. Gen. Psychol.* 16, 70–77. doi: 10.1037/a0026580
- Yasar, C., and Aral, N. (2012). Drama education on the creative thinking skills of 61-72 months old pre-school children. *US China Educ. Rev.* 6, 568–577.
- Yeh, Y.-C., and Li, M.-L. (2008). Age, emotion regulation strategies, temperament, creative drama, and preschoolers' creativity. *J. Creat. Behav.* 42, 131–149. doi: 10.1002/j.2162-6057.2008.tb01291.x

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# Improving Teenagers' Divergent Thinking With Improvisational Theater

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Improvisational theater (improv) is supposed to have an impact on cognitive processes (divergent thinking, flexibility, language, memory, problem solving, and co-construction), academic performance, and everyday life in many ways. However, little research studied on the psychological impact of improv, with some results highlighting a divergent thinking enhancement in children and adults, but not with teenagers, one of the most important age groups to practice improv. Therefore, this study aims to assess divergent thinking for middle school students before and after an 11-weeks session compared to a control group with a sport practice. The Alternative Uses Task (AUT) was used before and after the session for both groups to evaluate divergent thinking. The improv group had better performance in originality, flexibility and gave less prototypical items after the improv sessions compared to before, while the control group performance was similar before and after. Our results suggest that improv helps teenagers' divergent thinking to improve, not only with experimental games in the lab context but also after ecological sessions. We urge scientists to study in depth psychological impacts of improvisational theater and applied improvisation, for a better understanding of improv and as a model to study embodied cognition.

**Keywords:** improv, divergent thinking, pedagogy, school, embodiment, action

## INTRODUCTION

In a fast changing century, many people in arts, science, teaching, management, or technology wonder how to innovate and produce novel and useful resources, which are the most widely accepted elements regarding the definition of creativity (Sternberg and Lubart, 1993; Ritter and Mostert, 2017). Considering this necessity to develop good creativity skills, many people turn to arts, mostly theater and music. In this context, the success of improvisational theater (improv), supposed to enhance creativity (Bermant, 2013), spreads into various areas beyond theater (i.e., applied improvisation): medical doctors, psychologists, teachers, students, managers, negotiators and scientists attend improv workshops (Bermant, 2013; Bernstein, 2014; Hainselin et al., 2017b; Hoffmann-Longtin et al., 2017). The effects of improv on creativity, claimed by improv teacher, have not yet been studied extensively in cognitive sciences. The most of these studies used some improv games but not a full cycle usually used in improv training (Lewis and Lovatt, 2013; Sowden et al., 2015). The current project aims to focus on the impact of an ecological improv cycle on teenagers, which have never been studied, in our knowledge. In the remaining part of

the introduction, we will focus on one aspect of creativity (divergent thinking) and psychological impact of improvisation.

## Divergent Thinking

Classic creativity models include the implication of associative processes (Megalakaki et al., 2012). Lubart (2001, p. 295) specified the cognitive processes involved in creativity as “a capacity to produce many ideas (fluency), an ability to change one’s mental set (flexibility), an ability to reorganize, an ability to deal with complexity, and an ability to evaluate.” Creativity includes divergent thinking and convergent thinking. Divergent thinking supposed to generate multiple different answers or to think “out of the box.” One of its most common evaluations is the generation of alternative ideas, as assessed in the Alternative Uses Task (AUT; Guilford, 1967). Convergent thinking is the ability to find the most coherent idea of several answers. This knowledge dependent “evaluation of the novelty” interacts with divergent thinking and is “most effective in situations where a ready-made answer exists and need simply to be recalled from stored information” (Cromptley, 2006). While it is commonly admitted that creativity is both divergent and convergent thinking, the latter is sometimes referred to as “uncreative” (Ritter and Ferguson, 2017) and previous research pinpointed that divergent thinking is a widely accepted measure of creativity (Runco and Acar, 2012; Kenett et al., 2014). Mumford’s team (1991) proposed a model highlighting eight core processing activities for creative efforts: (1) problem definition, (2) information encoding, (3) category search, (4) specification of best-fitting categories, (5) combination and reorganization of best-fitting categories, (6) idea evaluation, (7) implementation, and (8) monitoring. Although, these eight processes should be taken into account for creativity assessment, Mumford et al. (2008), in a Silvia’s et al. (2008) team commentary paper, wrote that the idea generation measure used in this latter study is consistent with the traditional approach in the literature, probably for feasibility issues. Mumford et al. (1991) suggest that this kind of output-based measure might mostly reflect the idea generation process and not all of the eight they highlighted. While we believe research should focus on assessing these eight core processing activities, we also know that it is very time consuming and not always possible in ecological evaluation, especially with children and teenagers.

Many psychological factors, cognitive and emotional, can influence divergent thinking (for review and full description of cognitive processes involved, see Megalakaki et al., 2012). In its early research, Guilford scored his task for flexibility (changing from one idea to the others) and fluency (producing different ideas), two dimensions widely highlighted in the literature in divergent thinking assessments. Heuristics and information processing (including the associative processes of binding) also influence divergent thinking; they can be related to associative and executive processes (i.e., updating, switching, inhibition; Beaty et al., 2014). The role of associative processes, as well as executive control, seems to be particularly important to divergent thinking (Forthmann et al., 2016). Indeed, connecting the dots in a particular way, due to

good associative process, might lead to see patterns where others cannot; in other words, it can be the combination of remote associations into new and useful combinations (Kenett et al., 2014). The associative processes have strong connections with memory to help creativity processes to emerge (for extended discussion, see Jung and Vartanian, 2018). Personality factors, notably openness, risk taking and perseverance also have an impact on divergent thinking (Lubart et al., 2009).

## Improvisational Theater

Improvisational theater (improv) is a specific theater form in which the performance is spontaneous (i.e., without previous scenario written nor prepared). In this condition, going on stage without a single prepared word, costume or décor requires risk taking and perseverance to keep falling and getting up for every performance (Johnstone, 1999; Bermant, 2013). Hoffmann-Longtin et al. (2017) recently pinpointed that rather being innately spontaneous, “professional improvisers develop the ability to listen closely, focus, accept others’ ideas and support one another through improvisation games.” In its improv manual, Tournier (2001) highlights 10 values including to listen, accept, build, innovate and dare to. In other words, we can argue that improv is supposed to develop processes that can be referred to as executive functions (such as flexibility and fluency), information processing (including binding), in addition to risk taking and perseverance. Although, there is very few psychological science papers on cognitive processes involved in improv, we can highlight that these processes are very similar to those involved in divergent thinking. Beyond this obvious overlap, previous improv papers involved cognitive evaluation.

## Cognitive Impact of Improvisation

Improv teachers, learners, and scientists involved in improv (Bermant, 2013; Bernstein, 2014) or jazz improvisation (Doyle, 2017) usually demonstrate higher levels of creativity, memory, well-being, and less anxiety, all of which may be possible improv benefits (Bermant, 2013). However, there is little scientific evidence for these supposed benefits.

The emotional impact of improv was only very recently assessed to find it can help reduce anxiety and depression in young and older (27–72 years old) adults (Krueger et al., 2017). At our knowledge, only one study assessed the impact of improv on memory and showed a better ability to remember a dramatic text when played in an improvisation scene condition compared to reading only or writing about the scene or group discussions conditions (Scott et al., 2001). This result is consistent with the enactment effect (i.e., better memory for performed actions than for verbally encoded action sentences) and the embodied nature of improv (Borghini and Caruana, 2015; Hainselin et al., 2017a). In its history, cognitive and physical dimensions of improv were always very important, including its name. In the 1970’s, it was difficult to define improv as an alternative education tool, a theater or sport practice, leading to refer to as theatresport (Johnstone, 1999). Most of the studies used improv exercises thought to enhance divergent thinking, as



free walking (Kuo and Yeh, 2016), in jazz music (Benedek et al., 2014), spontaneous sentences and conversation (Lewis and Lovatt, 2013) or gesture while speaking (Lewis et al., 2015). If there is some evidence that improv increases divergent thinking during adulthood, these researches used laboratory situation with specific exercises, very different from the standard improv courses. Moreover, they did not use a physical activity control group to distinguish between the divergent thinking due to specific improv courses and physical activity's effect. Improv games for elementary school children found similar impact on divergent thinking than for adults (Sowden et al., 2015). In both studies with adults (Lewis and Lovatt, 2013) and children (Sowden et al., 2015), participants only took part in a short session of improv games, but no study assessed the impact of a more ecological improv program with multiple sessions of 1–2 h.

Thus, this study aimed to evaluate the impact of improv on teenagers' divergent thinking, following a standard course and if it differed from a sports control group. Adolescence is a critical period for cognitive development; there are many improv courses for teenagers in middle school but, as far we know, no scientific study on its impact yet.

## MATERIALS AND METHODS

### Participants

A total of 35 participants took part in this study; three of them were not included because of missing data or stopping an activity before the end; we also excluded 2 teenagers who skipped a grade to avoid age or intelligence differences. We included 18 participants (9 males and 9 females) for the improv group and 12 (8 males and 4 females) for the control group; all of them were seventh graders. There was no significant age (improv group mean = 11.39;  $SD = 0.50$ ; control group mean = 11.75;  $SD = 0.62$ ) [ $t(20.166) = 1.681$ ,  $p = 0.108$ ] nor gender [ $\chi^2(1) = 0.814$ ,  $p < 0.367$ ] differences between the groups. All of them were French speakers. All teenagers gave their written consent to be part of the research and we had approval from their parents, headmasters and teachers. None of them had neurological or psychiatric history, nor developmental learning disorder.

### Materials

The AUT is a task based on Guilford work (1967). Participants had to list as many possible uses for common items. We had the same methodology than Lewis and Lowatt paper (2013): the two items were a paperclip and a remote control and participants had 3 min to list alternative uses for each item. Scoring comprised of five components:

- (1) Prototypical items: Number of prototypical response. For paperclip, prototypical response would be “holding sheets of paper together” and for remote control “turn the volume down” or “change the channel.” The other four components are classical for AUT, but we added this fifth after observing 72% of our participants gave at least one prototypical use. In previous divergent thinking studies with similar task, it has

previously been taken into account as “standard actions” (Harrington et al., 1983) or “usual or popular responses” (Milgram et al., 1978).

- (2) Originality: How original each response is. We compared each response to every responses regarding one item. Responses with over 5% rate are considered common (0 point), between 1 and 5% unusual (1 point) and <1% ones as unique (2 points). The cumulated score of all given items for each item is the originality score. The more original the responses are, the higher the score is.
- (3) Fluency: Number of different responses for each item.
- (4) Flexibility: Number of different categories for each item. For example, if a participant wrote “necklace, ring and earring” as alternative uses for the paperclip, the flexibility score is 1, as there is one category (jewelry). For a participant who wrote “necklace, key and Christmas' tree decoration,” the flexibility score would be 3.
- (5) Elaboration: Amount of details. Each detail adds one point. For example, “a key” is 0 point but “a key to open the door which is always locked” is 2 points: 1 for the door opening and 1 for the always locked detail.

Considering the influence of fluency on originality (easier to have original answers within 20 propositions than in 5) and flexibility (more categories can be found within more answers), and regarding methodological recommendations (Clark and Mirels, 1970; Mouchiroud and Lubart, 2001), we calculated a ratio score by dividing prototypical items, originality and flexibility scores by the fluency score.

### Procedure

All participants took the AUT during the week preceding the first improv course for the pre-assessment and during the week after the last improv course for the post-assessment evaluation.

The 11 improvisation sessions took place in the teenagers' school, during lunchtime for 60 min session. Each session theme is described in Table 1. The control group participants were enrolled in a sport session for the same amount of time and frequency.

### Statistical Methodology

All data were analyzed with R 3.4.3 (R Core Team, 2017). All statistical analyses were, respectively, realized on the number of fluency and the ratio score of prototypical, flexibility, originality and elaboration items. We carried out each statistical analysis using repeated measured ANOVA with Group (Improv, Control) as between participants' factor and Condition (Pre-assessment, Post-assessment) as the within-participants factor.

All repeated measured ANOVA met the assumption of sphericity. When the assumption of normality of residuals was violated, the rank transformation was realized on the dependent variables (Zimmerman and Zumbo, 1993). The use of transformation was indicated in the statistical analysis.

The data and R script to replicate all statistical analyses are available on the Open Science Framework (OSF) platform at <https://osf.io/ysxer/>. Data are available in **Supplementary Material** as well.

## RESULTS

Regarding statistical methodology, we present rank transformed data for the ratio score of elaboration and number of fluency, but non-transformed data for the ratio score of prototypical items, originality and flexibility. In summary, for all analyses (Elaboration, Prototypical items, Originality, and Flexibility) except for Fluency, we used ratio scores. However, raw data are available in **Table 2** for readers who want the information.

### Prototypical Items

We found a main effect of Condition [ $F(1,28) = 9.713$ ,  $MSE = 0.045$ ,  $p = 0.004$ ,  $\eta_p^2 = 0.258$ ], with a higher prototypical

items ratio in pre- [ $M = 0.373$ ;  $SD = 0.323$ ] than post-assessment [ $M = 0.166$ ;  $SD = 0.228$ ], but no Group effect [ $F(1,28) = 0.004$ ,  $MSE = 0.103$ ,  $p = 0.952$ ,  $\eta_p^2 < 0.001$ ]. There was a Group  $\times$  Condition interaction [ $F(1,28) = 8.121$ ,  $MSE = 0.045$ ,  $p = 0.008$ ,  $\eta_p^2 = 0.225$ ], such as the improv group gave a smaller prototypical items ratio in the post-assessment compared to the control group while there was no difference in the pre-assessment (**Figure 1**).

### Fluency

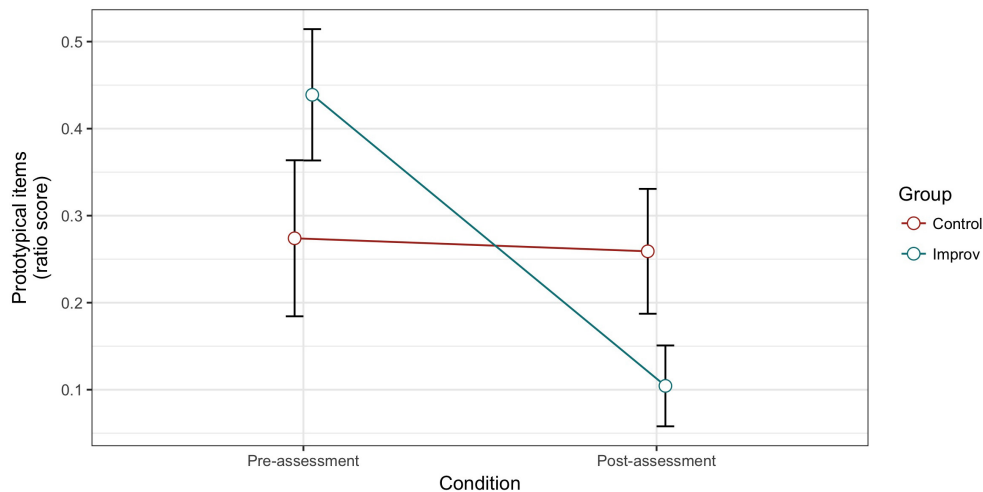
The ANOVA revealed a main effect for Condition [ $F(1,28) = 4.590$ ,  $MSE = 168.06$ ,  $p = 0.041$ ,  $\eta_p^2 = 0.141$ ], with more items in the post- ( $M = 4.94$ ;  $SD = 3.60$ ), than in

**TABLE 1** | Improv sessions description.

Session number	Theme	Example of improv games
Session 1	Presentation, introductory improv games	Zip Zap Zop: people pass the energy across the circle (in the form of a Zip, a Zap, or a Zop), they make eye contact with the person they send the energy to
Session 2	Co-construction	Listening to one other improviser's idea and add a detail to make this idea richer
Session 3	Emotions	Turning the emotion volume from 1 (a tiny smile) to 5 (being over the moon)
Session 4	Saying yes	Playing a scene without saying no to the other people idea, then saying "yes and" to it
Session 5	Characters	An imposed character is given to the improviser who has to play it (i.e., man on the moon, tired pupil)
Session 6	Reactivity	All participants had to rank themselves regarding different criteria (i.e., shoe size) within 20 s
Session 7	Improv categories	Categories included playing without moving or dubbing (one moves his/her lips while the other speaks)
Session 8	Listening	Walking with the eyes closed, only guided by another improviser's voice
Session 9	Imagination	Describe a world where you have never been previously
Session 10	Show preparation 1	Includes all previous sessions themes
Session 11	Show preparation 2	Includes all previous sessions themes

**TABLE 2** | Raw data, means, and standard deviation for each condition and group.

Index	Score	Improv ( $n = 18$ )			Control ( $n = 12$ )		
		$M$ ( $SD$ )	Skewness	Kurtosis	$M$ ( $SD$ )	Skewness	Kurtosis
<b>Pre-assessment</b>							
Fluency	Raw	4.111 (1.632)	0.360	-0.386	4.167 (1.249)	-0.508	-0.753
Prototypical	Raw	1.694 (1.426)	0.591	-0.639	0.958 (1.076)	0.952	-0.095
	Ratio	0.439 (0.320)	0.038	-1.399	0.274 (0.311)	0.917	-0.193
Originality	Raw	2.944 (3.038)	1.550	1.523	3.667 (2.462)	0.210	-1.564
	Ratio	0.691 (0.498)	0.342	-1.316	0.822 (0.434)	0.177	-1.304
Flexibility	Raw	2.111 (1.844)	1.556	1.894	2.958 (1.544)	-0.302	-1.753
	Ratio	0.478 (0.273)	0.398	-0.698	0.682 (0.249)	-0.562	-0.557
Elaboration	Raw	1.000 (0.728)	0.541	-0.324	1.583 (1.104)	0.132	-1.244
	Ratio	0.290 (0.267)	1.103	0.540	0.262 (0.404)	-0.114	-1.325
<b>Post-assessment</b>							
Fluency	Raw	6.222 (3.878)	1.397	2.102	4.458 (1.437)	-0.492	-1.004
Prototypical	Raw	0.472 (0.866)	2.393	5.486	1.125 (1.316)	1.231	0.820
	Ratio	0.104 (0.197)	1.940	2.616	0.259 (0.249)	0.462	-1.094
Originality	Raw	7.806 (6.576)	1.531	2.735	3.625 (2.196)	0.696	-0.851
	Ratio	1.514 (0.426)	-0.725	-0.330	0.812 (0.368)	0.147	-1.474
Flexibility	Raw	5.111 (3.871)	1.232	1.528	3.083 (1.663)	0.315	-1.678
	Ratio	0.786 (0.248)	-1.006	-0.461	0.683 (0.236)	-0.292	-1.187
Elaboration	Raw	1.472 (1.104)	0.747	-0.326	1.417 (2.043)	2.125	3.609
	Ratio	0.466 (0.907)	3.245	9.798	0.277 (0.336)	1.884	2.929



**FIGURE 1** | Alternative Uses Task (AUT) prototypical scores for pre- and post-test in the control and improv groups.

the pre-assessment ( $M = 2.94$ ;  $SD = 2.03$ ), but no Group effect [ $F(1,28) = 0.213$ ,  $MSE = 421.94$ ,  $p = 0.648$ ,  $\eta_p^2 = 0.008$ ] nor a Group  $\times$  Condition interaction [ $F(1,28) = 1.196$ ,  $MSE = 168.06$ ,  $p = 0.283$ ,  $\eta_p^2 = 0.041$ ].

### Flexibility

There was a main effect of Condition for flexibility [ $F(1,28) = 8.436$ ,  $MSE = 0.041$ ,  $p = 0.007$ ,  $\eta_p^2 = 0.232$ ], with higher ratio scores in the post-assessment ( $M = 0.745$ ;  $SD = 0.245$ ) than in the pre-assessment ( $M = 0.560$ ;  $SD = 0.279$ ) but no Group effect [ $F(1,28) = 0.412$ ,  $MSE = 0.088$ ,  $p = 0.526$ ,  $\eta_p^2 = 0.014$ ]. We found a Group  $\times$  Condition interaction [ $F(1,28) = 8.371$ ,  $MSE = 0.041$ ,  $p = 0.0072$ ,  $\eta_p^2 = 0.230$ ], such as the improv group had a higher ratio scores for different categories in the post- than pre-assessment compared to the control group for which there was no difference (Figure 2).

### Originality

The ANOVA conducted on the originality ratio score showed a Condition effect [ $F(1,28) = 6.999$ ,  $MSE = 0.105$ ,  $p = 0.013$ ,  $\eta_p^2 = 0.200$ ], with better performance in the post-assessment, but no Group effect [ $F(1,28) = 0.561$ ,  $MSE = 0.282$ ,  $p = 0.460$ ,  $\eta_p^2 = 0.020$ ]. In the same way, we find a significant Group  $\times$  Condition interaction [ $F(1,30) = 4.157$ ,  $MSE = 0.131$ ,  $p = 0.010$ ,  $\eta_p^2 = 0.214$ ], such as the Improv group outperformed the control group in the post-assessment condition while they did not differ in the pre-assessment (Figure 3).

### Elaboration

Using the ratio-ranked transformed data, there was no main effect of Group [ $F(1,28) = 0.341$ ,  $MSE = 385.89$ ,  $p = 0.564$ ,  $\eta_p^2 = 0.012$ ], Condition [ $F(1,28) = 1.903$ ,  $MSE = 223.76$ ,  $p = 0.179$ ,  $\eta_p^2 = 0.064$ ] nor Group  $\times$  Condition interaction [ $F(1,28) = 1.962$ ,  $MSE = 223.76$ ,  $p = 0.172$ ,  $\eta_p^2 = 0.065$ ].

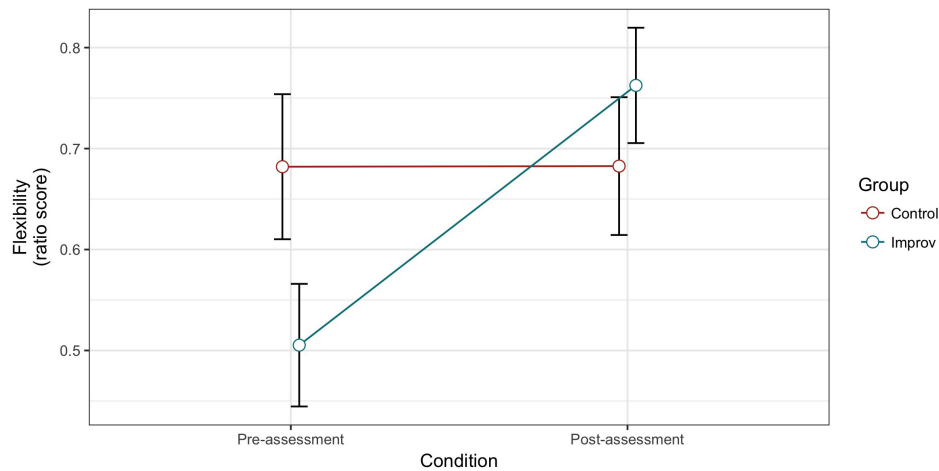
## DISCUSSION

Our preliminary results confirm that improv can help enhance divergent thinking skills. We are the first to demonstrate, in our knowledge, that this effect exists with middle school learners. We discuss these results at theoretical (divergent thinking) and applied levels for pedagogical purposes.

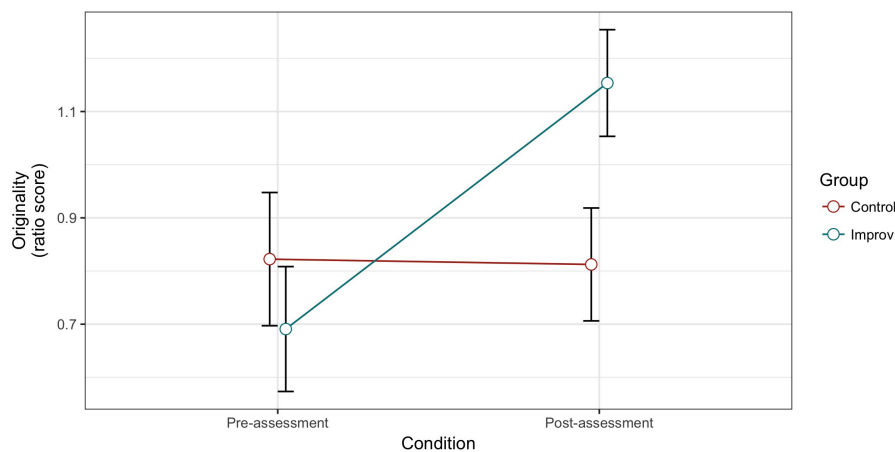
### Divergent Thinking Evaluations

We found a divergent thinking improvement with better results after improv for originality and flexibility, but no difference for fluency nor elaboration. Our results are consistent with short improv sessions improvements with children (Sowden et al., 2015) and adults (Lewis and Lovatt, 2013).

The AUT scores showed differences between groups, conditions and within themselves. We showed improv benefits for Prototypical items, Originality and Flexibility. The improv group gave less prototypical items after the session than before. Prototypical items were not evoked in previous papers using AUT (Akbari Chermahini et al., 2012; Lewis and Lovatt, 2013), although it has been scored in similar task (Milgram et al., 1978; Harrington et al., 1983). In this experiment, we do not know if our population was particular and might not understand the instructions (although nothing indicated it), if Prototypical items were included in the fluency scores or simply not a specific issue in previous papers. While Flexibility performance was better for the control group in the pre-assessment, no difference can be found with the improv group after the improv sessions. The Flexibility ratio (Flexibility/Fluency) improved only for the improv group, supporting the binding process enhancement with improv training hypothesis. Consistently with previous findings (Lewis and Lovatt, 2013), the improv group participants were more original (Originality ratio score) than the control group after the training. In an embodied cognition perspective, we could hypothesize that repeated practice improves skills (Ito, 2008) and leads to better knowledge or faster access to



**FIGURE 2** | Alternative Uses Task (AUT) flexibility scores for pre- and post-test in the control and improv groups.



**FIGURE 3** | Alternative Uses Task (AUT) originality scores for pre- and post-test in the control and improv groups.

it, thus to more different (original) items in the same amount of time. Koziol et al. (2012) argued that top down models cannot explain the continuously adaptive human behaviors and evolution leading directed to action control and not action *per se*. Future improv studies must focus on working memory, binding and control processes in general, beyond the classic executive functions definition (Miyake et al., 2000), with a double aim: a better understanding of improv impact and to develop a new way to investigate embodied cognition. The embodied cognition framework (Barsalou et al., 2003) is, in our opinion, the best to study improv. Barsalou (1999, p. 61) highlighted “the primary function of cognition is not to archive information but instead to prepare agents for situated action,” which is the core of improv.

On the null result side, there was no significant improvement for Fluency nor Elaboration. There is a Condition effect (post > pre) for the Fluency score, mostly due to the improv group improvement (+2.1 words on average) compared to the control group (+0.3 word on average), however, there was no Group × Condition interaction so we cannot conclude to an

improv specific Fluency improvement here. This unexpected result is likely due to the important standard deviation in the improv group post-assessment, and might be different with a bigger sample. On the qualitative side, it highlights the heterogeneous profile and progress of teenagers and the need to address their psychological profile more extensively, including non-creative fluency (i.e., verbal category fluency test) and language skills in general. The absence of Elaboration difference was less of a surprise. Indeed, we can wonder if the classic Elaboration instructions are explicit enough. Nothing tells they have to elaborate their answer. In the school context, learners could give a simple short answer when nothing elaborate is asked, just because it was not asked. Learners, when they are in a group, tend to follow the exact instructions and their critical mind is not always at its best (Lacot et al., 2016). While the AUT is a widely used divergent thinking assessment, the instructions might need to be adapted, at least for children and teenagers.

Beyond confirming previous results, these results are consistent with children and adults’ positive impact of improv

on divergent thinking. This suggests that the theater part of improv (also known as theatresports) has some importance in the divergent thinking enhancement, considering the difference with our sports control group. We believe further researches are needed to confirm our results in different ecological situations and population. Moreover, an in depth evaluation of improvisers' cognitive and emotional profiles will be needed to understand which improv components help enhancing divergent thinking.

## Pedagogical Issues

While the research on improv might be trending in a few years, the educational impact has been the center of attention for decades. The French Education Ministry recently endorsed improv as a learning tool (Eduscol, 2017), consistent with recent projects involving with teachers and students (Hainselin et al., 2017b). In France, not only politics but the media focused their attention on improv, with a recent documentary *Liberté, Égalité, Improvisez* (Freedom, Equality, Improvise, based on France motto Liberty Equality, Fraternity), following teenagers enrolled in the *Trophée Culture et Diversité* (Culture and Diversity Trophy), a popular improv national tournament (Rotschild and Bergeon, 2014). Teenage improvisers, their teachers and parents praised for improv benefits in the classroom: academic performance, but also well-being, speaking in public skills and creativity. Robert Gravel, Canadian co-creator of the improvisational game, said: "The more rigid the structure, the more immovable the playing area is, the tougher the referee is, the more impeccable the MC is, then the more the madness is allowed within the game" (Lavergne and Gravel, 1993). Although, we obviously prefer divergent thinking over madness, the artistic point of view converges with scientific evidence. Gravel emphasized the need for a well-designed and prepared frame to enhance creation and richer play, which can be translated into cognitive flexibility and divergent thinking. Stanislavski (2013), famous Actor's Studio inspirational model, also encouraged his actors and trainees to go beyond the classical "as if" to enhance personality, emotional and physical believability by demanding to embody the character.

These artistic anecdotes, combined with the growing literature on improv should encourage more researchers to run large-scale scientific research to assess the psychological impact of improv. A special focus is needed on teenagers, a very critical period in personality's development and well-being (Moreira et al., 2015), notably in intellectually gifted (Villatte and de Léonardis, 2012). In this perspective, a study is being conducted to determine the impact of improv exercises on emotional aspects (i.e., anxiety, self-esteem and well-being) in intellectually gifted teenagers. The instantaneous adaptation to unexpected events, a core skill developed in improv, can benefit far beyond teenagers in their school environment. Previous research suggests

improv can enhance adaptive behavior and metacognition (Biasutti, 2017). A recent paper highlights the benefits of applied improvisation for medical students' training (Hoffmann-Longtin et al., 2017). One of the twelve tips "collaborate with experts in university theater departments, community theaters and/or improvisation ensembles" is particularly relevant for middle and high schools too, in collaboration with psychologists and psychology researchers. More particularly, the period of high performance, synchrony and enhanced sense of togetherness in improv, named "being in the zone" by Noy et al. (2015), is a very promising topic of research. In conclusion, improvisational theater (improv) helps teenagers improving divergent thinking. While future research is needed on this topic, we hope other specific psychological topics (i.e., memory, executive functions, anxiety, well-being, etc.) will be studied within the improv practice through lifespan.

## AUTHOR CONTRIBUTIONS

MH designed the study and wrote the manuscript. AA ran the statistical analyses and drafted the manuscript. BB designed the study and drafted the manuscript.

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## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fpsyg.2018.01759/full#supplementary-material>

## REFERENCES

- Akbari Chermahini, S., Hickendorff, M., and Hommel, B. (2012). Development and validity of a dutch version of the remote associates task: an item-response theory approach. *Think. Ski. Creat.* 7, 177–186. doi: 10.1016/j.tsc.2012.02.003
- Barsalou, L. W. (1999). Language comprehension: archival memory or preparation for situated action? *Discourse Process.* 28, 61–80. doi: 10.1080/01638539909545069
- Barsalou, L. W., Kyle Simmons, W., Barbey, A. K., and Wilson, C. D. (2003). Grounding conceptual knowledge in modality-specific systems. *Trends Cogn. Sci.* 7, 84–91. doi: 10.1016/S1364-6613(02)00029-3

- Beatty, R. E., Silvia, P. J., Nusbaum, E. C., Jauk, E., and Benedek, M. (2014). The roles of associative and executive processes in creative cognition. *Mem. Cogn.* 42, 1186–1197. doi: 10.3758/s13421-014-0428-r8
- Benedek, M., Borovnjak, B., Neubauer, A. C., and Kruse-Weber, S. (2014). Creativity and personality in classical, jazz and folk musicians. *Pers. Individ. Dif.* 63, 117–121. doi: 10.1016/j.paid.2014.01.064
- Bermant, G. (2013). Working with(out) a net: improvisational theater and enhanced well-being. *Front. Psychol.* 4:929. doi: 10.3389/fpsyg.2013.00929
- Bernstein, R. (2014). Communication: spontaneous scientists. *Nature* 505, 121–123. doi: 10.1038/nj7481-121a
- Biasutti, M. (2017). Teaching improvisation through processes. Applications in music education and implications for general education. *Front. Psychol.* 8:911. doi: 10.3389/fpsyg.2017.00911
- Borghini, A. M., and Caruana, F. (2015). “Embodiment Theory,” in *International Encyclopedia of the Social & Behavioral Sciences*, eds N. J. Smelser and P. B. Baltes (Berlin: Elsevier), 420–426. doi: 10.1016/B978-0-08-097086-8.56025-r5
- Clark, P. M., and Mirels, H. L. (1970). Fluency as a pervasive element in the measurement of creativity. *J. Educ. Meas.* 7, 83–86. doi: 10.1111/j.1745-3984.1970.tb00699.x
- Cropley, A. (2006). In praise of convergent thinking. *Creat. Res. J.* 18, 391–404. doi: 10.1207/s15326934crj1803\_13
- Doyle, C. L. (2017). Creative flow as a unique cognitive process. *Front. Psychol.* 8:1348. doi: 10.3389/fpsyg.2017.01348
- Eduscol (2017). *Pratique de l'improvisation Théâtrale [Improvisational theatre practice]*. Available at: <http://eduscol.education.fr/cid114218/pratique-de-l-improvisation-theatrale.html> [accessed September 1, 2017].
- Forthmann, B., Gerwig, A., Holling, H., Çelik, P., Storme, M., and Lubart, T. (2016). The be-creative effect in divergent thinking: the interplay of instruction and object frequency. *Intelligence* 57, 25–32. doi: 10.1016/j.intell.2016.03.005
- Guilford, J.-P. (1967). *The Nature of Human Intelligence*. New York, NY: McGraw-Hill.
- Hainselin, M., Picard, L., Manolli, P., Vankerkore-Candas, S., and Bourdin, B. (2017a). Hey teacher, don't leave them kids alone: action is better for memory than reading. *Front. Psychol.* 8:325. doi: 10.3389/fpsyg.2017.00325
- Hainselin, M., Quillico, M., and Parking, G. (2017b). L'improvisation: une pédagogie de l'expérimentation [Improvisation: an experimentation pedagogy]. *Les Cah. Pédagogiques* 535, 43–44.
- Harrington, D. M., Block, J., and Block, J. H. (1983). Predicting creativity in preadolescence from divergent thinking in early childhood. *J. Pers. Soc. Psychol.* 45, 609–623. doi: 10.1037/0022-3514.45.3.609
- Hoffmann-Longtin, K., Rossing, J. P., and Weinstein, E. (2017). Twelve tips for using applied improvisation in medical education. *Med. Teach* 40, 351–356. doi: 10.1080/0142159X.2017.1387239
- Ito, M. (2008). Control of mental activities by internal models in the cerebellum. *Nat. Rev. Neurosci.* 9, 304–313. doi: 10.1038/nrn2332
- Johnstone, K. (1999). *Improv for Storytellers: Theatresports and the Art of Making Things Happen*. London: Faber & Faber.
- Jung, R. E., and Vartanian, O. (2018). *The Cambridge Handbook of the Neuroscience of Creativity*, eds R. E. Jung and O. Vartanian (Cambridge: Cambridge University Press), doi: 10.1017/9781316556238
- Kenett, Y. N., Anaki, D., and Faust, M. (2014). Investigating the structure of semantic networks in low and high creative persons. *Front. Hum. Neurosci.* 8:407. doi: 10.3389/fnhum.2014.00407
- Kozioł, L. F., Budding, D. E., and Chidekel, D. (2012). From movement to thought: executive function. *Embodied Cogn. Cereb. Cereb.* 11, 505–525. doi: 10.1007/s12311-011-0321-y
- Krueger, K. R., Murphy, J. W., and Bink, A. B. (2017). Thera-prov: a pilot study of improv used to treat anxiety and depression. *J. Ment. Health* doi: 10.1080/09638237.2017.1340629 [Epub ahead of print].
- Kuo, C.-Y., and Yeh, Y.-Y. (2016). Sensorimotor-conceptual integration in free walking enhances divergent thinking for young and older adults. *Front. Psychol.* 7:1580. doi: 10.3389/fpsyg.2016.01580
- Lacot, E., Blondelle, G., and Hainselin, M. (2016). From bill shankly to the huffington post: how to increase critical thinking in experimental psychology course? *Front. Psychol.* 7:538. doi: 10.3389/fpsyg.2016.00538
- Lavergne, J.-M., and Gravel, R. (1993). *Impro Réflexions et Analyses*. Outremont, QC: Léméac.
- Lewis, C., Lovatt, P., and Kirk, E. (2015). Many hands make light work: the facilitative role of gesture in verbal improvisation. *Think. Ski. Creat.* 17, 149–157. doi: 10.1016/j.tsc.2015.06.001
- Lewis, C., and Lovatt, P. J. (2013). Breaking away from set patterns of thinking: improvisation and divergent thinking. *Think. Ski. Creat.* 9, 46–58. doi: 10.1016/j.tsc.2013.03.001
- Lubart, T., Georgsdottir, A., and Besançon, M. (2009). “The nature of creative giftedness and talent,” in *The Routledge International Companion to Gifted Education*, eds T. Balchin, B. Hymer, and D. J. Matthews (Oxford: Routledge), 42–49.
- Lubart, T. I. (2001). Models of the creative process: past, present and future. *Creat. Res. J.* 13, 295–308. doi: 10.1207/S15326934CRJ1334\_07
- Megalakaki, O., Craft, A., and Cremin, T. (2012). The nature of creativity: cognitive and confluence perspectives. *Electron. J. Res. Educ. Psychol.* 10, 1035–1056. doi: 10.25115/ejrep.v10i28.1548
- Milgram, R. M., Milgram, N. A., Rosenbloom, G., and Rabkin, L. (1978). Quantity and quality of creative thinking in children and adolescents. *Child Dev.* 49:385. doi: 10.2307/1128702
- Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., and Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: a latent variable analysis. *Cogn. Psychol.* 41, 49–100. doi: 10.1006/cogp.1999.0734
- Moreira, P. A. S., Cloninger, C. R., Dinis, L., Sá, L., Oliveira, J. T., Dias, A., et al. (2015). Personality and well-being in adolescents. *Front. Psychol.* 5:1494. doi: 10.3389/fpsyg.2014.01494
- Mouchiroud, C., and Lubart, T. (2001). Children's original thinking: an empirical examination of alternative measures derived from divergent thinking tasks. *J. Genet. Psychol.* 162, 382–401. doi: 10.1080/00221320109597491
- Mumford, M. D., Mobley, M. I., Reiter-Palmon, R., Uhlman, C. E., and Doares, L. M. (1991). Process analytic models of creative capacities. *Creat. Res. J.* 4, 91–122. doi: 10.1080/10400419109534380
- Mumford, M. D., Vessey, W. B., and Barrett, J. D. (2008). Commentary: Measuring divergent thinking: is there really one solution to the problem? *Psychol. Aesthetics Creat. Arts* 2, 86–88. doi: 10.1037/1931-3896.2.2.86
- Noy, L., Levit-Binun, N., and Golland, Y. (2015). Being in the zone: physiological markers of togetherness in joint improvisation. *Front. Hum. Neurosci.* 9:187. doi: 10.3389/fnhum.2015.00187
- R Core Team (2017). *R: A Language and Environment for Statistical Computing*. Vienna: R Foundation for Statistical Computing.
- Ritter, S. M., and Ferguson, S. (2017). Happy creativity: listening to happy music facilitates divergent thinking. *PLoS One* 12:e0182210. doi: 10.1371/journal.pone.0182210
- Ritter, S. M., and Mostert, N. (2017). Enhancement of creative thinking skills using a cognitive-based creativity training. *J. Cogn. Enhanc.* 1, 243–253. doi: 10.1007/s41465-016-0002-3
- Rotschild, A., and Bergeon, E. (2014). *Liberté, Égalité, Improvisez [Liberty, Equality, Improvise]*. Paris: 416 Prod.
- Runco, M. A., and Acar, S. (2012). Divergent thinking as an indicator of creative potential. *Creat. Res. J.* 24, 66–75. doi: 10.1080/10400419.2012.652929
- Scott, C. L., Harris, R. J., and Rothe, A. R. (2001). Embodied cognition through improvisation improves memory for a dramatic monologue. *Discourse Process.* 31, 293–305. doi: 10.1207/S15326950dp31-3\_4
- Silvia, P. J., Winterstein, B. P., Willse, J. T., Barona, C. M., Cram, J. T., Hess, K. I., et al. (2008). Assessing creativity with divergent thinking tasks: exploring the reliability and validity of new subjective scoring

- methods. *Psychol. Aesthetics Creat. Arts* 2, 68–85. doi: 10.1037/1931-3896.2.2.68
- Sowden, P. T., Clements, L., Redlich, C., and Lewis, C. (2015). Improvisation facilitates divergent thinking and creativity: realizing a benefit of primary school arts education. *Psychol. Aesthetics Creat. Arts* 9, 128–138. doi: 10.1037/aca0000018
- Stanislavski, C. (2013). *An Actor Prepares*. London: Bloomsbury Academic.
- Sternberg, R. J., and Lubart, T. I. (1993). Creative giftedness: a multivariate investment approach. *Gift. Child Q.* 37, 7–15. doi: 10.1177/001698629303700102
- Tournier, C. (2001). *300 Exercices D'improvisation et D'exploration Theatrale*. Paris: Eau Vive.
- Villatte, A., and de Léonardis, M. (2012). «Qui suis-je?» Quelques spécificités du discours sur soi à l'adolescence chez les sujets à haut potentiel intellectuel. *Neuropsychiatr. Enfance. Adolesc.* 60, 101–107. doi: 10.1016/j.neurenf.2011.09.002
- Zimmerman, D. W., and Zumbo, B. D. (1993). Relative power of the wilcoxon test, the friedman test, and repeated-measures ANOVA on ranks. *J. Exp. Educ.* 62, 75–86. doi: 10.1080/00220973.1993.943832

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# The Relationships Between Cognitive Reserve and Creativity. A Study on American Aging Population

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The Cognitive Reserve (CR) hypothesis suggests that the brain actively attempts to cope with neural damages by using pre-existing cognitive processing approaches or by enlisting compensatory approaches. This would allow an individual with high CR to better cope with aging than an individual with lower CR. Many of the proxies used to assess CR indirectly refer to the flexibility of thought. The present paper aims at directly exploring the relationships between CR and creativity, a skill that includes flexible thinking. We tested a sample of 72 adults (aged between 45 and 78) assessing both their level of CR and their creativity. To evaluate CR we used the proxies commonly used in literature, namely, three subtests from the WAIS (vocabulary, similarities, and digit span) and the years of education. We also used an *ad-hoc* test asking people to report how frequently they tend to perform activities that are believed to increase CR. We used verbal creativity tasks (alternative uses and generation of acronyms) to assess individual levels of creativity. We asked participants to describe their main occupation (present or past) and coded each occupation as creative or not creative. Results (controlling for age-related differences) showed that scores from the WAIS correlated positively with creativity performance, even though correlations varied across the subtests. Focusing on the frequency and type of activities that people perform, and comparing individuals who have or had a creative job to those with a routine job, a clear relationship between creativity and CR emerged. This effect was more relevant than the level of job complexity. Implications for the study of CR and aging are discussed.

**Keywords:** cognitive reserve, aging, creativity, WAIS, flexibility

## INTRODUCTION

The reserve hypothesis has been introduced by Stern (2002, 2006, 2009) to explain individual differences that allow some people to cope better than others with brain damage. This line of research has been inspired by the evidence that in some elderly, despite the presence of considerable brain pathology, no clinically-observable signs or symptoms of a disease are reported (Mortimer et al., 2003). The reserve model explains this disparity by referring to differences in the cognitive processes or neural networks underlying task performance. People with higher reserve can “optimize or maximize performance through differential recruitment of brain networks, which perhaps reflect the use of alternate cognitive strategies” (Stern, 2002, p. 451). Interestingly, Stern (2009) also noted that the reserve is relevant not just to the onset of dementia or other neurological,



age-related diseases, but also to normal aging, as it allows the aging population to cope more efficiently with age-related brain changes.

The reserve hypothesis refers to two different models (see Stern, 2002, 2006, 2009 for extensive reviews): the passive and the active one. The passive model is also defined as the “Brain Reserve” and refers to the positive relationship between the brain size and the ability to cope with pathology without showing signs of clinical impairment (Stern, 2009). The active model is usually referred to as “Cognitive Reserve” (CR) and suggests that different life experiences (such as education, occupation, and cognitively-stimulating leisure activities) provide a shield against the effects of brain damage or pathology, helping the individual to cope by enlisting compensatory processes and slowing down memory decline in normal aging (Stern, 2009).

In this paper we are going to refer to the active model, focusing on CR and its possible relationship with creativity. This relationship can be speculatively inferred by reflecting on the proxies that are commonly used to measure CR. The reason why proxies are needed is that CR cannot be directly measured, as is the case for the brain reserve. For this reason, it is commonly assessed indirectly by evaluating experiences and activities that are believed to increase it. As mentioned above, the most commonly-used proxy measures refer to educational level and literacy (Stern et al., 1992; Manly et al., 2003, 2005), occupational status, with a specific attention to occupational complexity (Stern et al., 1994; Richards and Sacker, 2003; Staff et al., 2004), and engagement in cognitively-stimulating leisure activities (e.g., Wilson et al., 1999; Aartsen et al., 2002; Mousavi-Nasab et al., 2014; Colombo et al., 2018). The cohesion of social networks (Fratiglioni et al., 2000; Bennett, 2006; Colombo et al., 2018) and personality variables have been incorporated into CR, too (Bennett et al., 2006; Wilson et al., 2007). A good example of how these proxies can be integrated together can be found in the critical evaluation of the Cognitive Reserve Index questionnaire developed and validated by Nucci et al. (2012).

A recent meta-analysis (Opdebeeck et al., 2016) supports the idea that indices of CR are related to cognitive function in some different domains, although the reported associations are modest. The authors stressed the need for further studies to more comprehensively investigate the relationships between CR and specific, well-defined, cognitive functions in healthy and clinical populations. Creativity might be one of these functions.

Starting from these remarks, we decided to focus on the possible relationship between CR (assessed by using education levels, occupation complexity, and number and frequency of leisure activities, as well-intelligence tests) and creativity (assessed using tasks asking to list as many responses as possible to given stimuli, as often occurs in the assessment of creative skills) in a healthy aging population. The reason for exploring this relationship originates from a definition of creativity that, trying to go beyond differences among different theoretical perspectives, highlights the common cognitive principles behind all of them (Antonietti and Colombo, 2013, 2016). From this perspective, creativity can be declined as three mental operations: widening (the tendency to keep an open mind and be able to deal with a high number of elements), connecting (the capacity to

establish relationships among different elements and to combine them in unusual ways), and reorganizing (being able to change perspective and invert relationships among elements). CR, as discussed above, has been defined as a factor that allows the aging population to use alternative strategies to better cope with age-related brain damages. Skills required for doing so appear to be similar to the ones, listed above, that characterize the creative process. Accessing and applying alternative strategies require an individual to be able to keep an open mind, establish new and unusual relationships, and change perspective as requested.

We were hence hypothesizing to find a positive relationship between levels of CR and levels of creativity in our participants. A recent study (Palmiero et al., 2016) investigated the possibility of using creativity as a proxy for CR. Results highlighted that verbal creativity, but not visual creativity, predicts CR. Other recent studies explored more indirectly constructs that could be related to creativity. If is true that creative thinking can be seen as the result of the concurrent activation of several neural networks (see, for example, Beaty et al., 2015), the dorsolateral prefrontal cortex (DLPFC) in particular appears to regulate some aspects of the creative process (e.g., Chrysikou et al., 2013; Iannello et al., 2014; Colombo et al., 2015; Weinberger et al., 2017) and flexibility in thinking (Oldrati et al., 2016, 2018). For this reason, studies reporting a role of the DLPFC in moderating CR are particularly relevant to our investigation. Roldán-Tapia et al. (2012) and Arcara et al. (2017) focused on the relationships between the CR and several cognitive and executive functions. Results highlighted that CR levels (mainly education in Arcara and colleagues' study) contribute significantly to the performance in tasks that refer back to functions mainly related to the dorsolateral prefrontal area. Another study applying rTMS over the DLPFC (Manenti et al., 2011) on a sample of healthy older adults led the authors to conclude that left DLPFC rTMS during encoding only resulted in a disruptive effect among elders exhibiting low memory performance but not among high performing elders, suggesting that the underlying mechanisms in the latter group imply a more distributed recruitment of the contralateral DLPFC to counteract age-related functional brain loss.

Studies exploring, directly or indirectly, the relationship between CR and creativity report are at an exploratory level, hence collecting more data using different measures, as suggested by Palmiero et al. (2016), to confirm these initial findings seems to be relevant.

## METHODS

### Sample

Seventy-two healthy individuals, aged between 42 and 78 (Mean = 58.67; SD = 12.31), joined the study. They were not balanced by gender (women = 66.7%). Participants were recruited through posts on local newspapers and by contacting local senior centers. All participants were from North and central Vermont and had a high or middle SES. We followed the APA suggested best practices for measuring socioeconomic status (<http://www.apa.org/pi/ses/resources/class/measuring-status.aspx>). We measured Education and Occupation (used to assess the CR as well, see details

below) and also asked participants to report the average family income. Participants who reported symptoms or diagnosis linked to dementia or other age-related disorders were excluded.

As a compensation for the time participants spent in taking part to the present study, after the assessment they received a free 15-week program designed to enhance the CR by the way of suggesting relevant activities targeting different proxies reported in the literature as effective to increase CR.

## Tools

### Wechsler Adult Intelligence Scale (WAIS)

Subtests from the WAIS-IV (Wechsler, 2008)—namely, Vocabulary, Similarities, and Digit Span (forward and backward)—have been used. The Vocabulary subset assesses word knowledge and verbal concept formation. The Similarities subtest measures verbal concept formation and reasoning. The Digit Span subtest focuses on working memory. These subtests have been reported and used in the literature as a measure of CR (see, for example, Corral et al., 2006; Solé-Padullés et al., 2009; Roldán-Tapia et al., 2012).

The assessment was performed following the instructions indicated in the manual of the WAIS-IV. The conditions of test application were constant for all participants. Subtests were applied individually in one session. A trained research assistant performed all the evaluations.

### CoRe-T

To include the specific proxies linked to CR and to assess creative thinking, we used an *ad-hoc* questionnaire, CoRe-T (Cognitive Reserve Test). The questionnaire includes two main sections (self report and creative tasks) and five subsections:

1. Self-report data
  - a. Education: We asked people to report the years of completed education, including vocational training. Participants were also asked to list each degree, diploma, and certificate together with the year it was earned.
  - b. Leisure activities: Participants were presented with a list of 17 leisure activities derived from the ones reported in the literature as linked to CR (see Appendix 1 for the complete list of activities). For each activity, they were asked to rate (on a 5-point Likert scale, where 1 corresponded to rarely/never and 5 to often/every day) the frequency of performing that activity. Respondents were also asked to report an estimate of the numbers of years they have been performing that specific activity. Years of activity were defined as the highest consecutive number of years performing the activity by using a 3-point Likert scale (1 = 1 year or less; 2 = 2–5 years; 3 = 5 years or more). A total score of CR as represented by the frequency of performing leisure activities was devised by computing the mean score of the reported frequencies for all 17 leisure activities listed in the CoRe-T.
  - c. Occupation history: Participants were asked to list the general type of occupation, the specific position(s) they had, and the number of years they have been working in each position.

2. Creative tasks Two tasks commonly used to assess verbal creative abilities were chosen to be included in the CoRe-T.

- a. Acronyms (Guilford, 1967): Participants were given 5 min to list all the terms that can fit into the three given acronyms (SOS—OMG—TGIF). The terms had to make sense together.
- b. Alternative uses (Guilford, 1967; Torrance, 1990): Participants were given 5 min to list as many different, interesting or unusual usages for an empty plastic bottle as they could.

Participants' answers to the two creative tasks have been scored following the guidelines derived from the Torrance Test of Creative Thinking (Torrance, 1990). For each task we computed a fluidity score by counting the numbers of valid answers. Invalid answers for the acronym task were defined as answers using non-existing words or using terms that did not make sense together. Invalid answers for the alternative use tasks were answers according to which bottles are used as bottles (hence not providing any new use) or where the use of bottles is missing. Two researchers coded all the answers independently. An originality score was computed as well. After reading all the answers for each task in order to derive a list of the most common answers, a list of original (i.e., not listed among the most frequently reported uses) answers has been compiled by two researchers. Each individual answer was then coded as original (1) or not original (0). A final score was computed by adding the number of original answers. Cases of disagreement in scoring responses to the creative tasks were discussed and resolved case by case by the two researchers.

### Procedure

The study has been approved by Champlain College IRB committee.

Participants who expressed an interest in being involved in the study were contacted by a member of the research team to check for eligibility criteria. Eligible participants booked an appointment to be individually tested. Before starting the assessment, participants were given the Informed Consent and were asked to sign it. They were also given the possibility to ask any questions they might have.

After this preliminary phase, the three subtests of the WAIS-IV were administered, followed by the CoRe-T. At the end of the session, participants were offered to have either a printed or a digital copy of a training program designed to increase their CR. The program suggests weekly activities targeting different proxies reported in the literature as effective to increase CR.

## RESULTS

Before running specific analyses, we checked the dataset looking for possible outliers. None emerged, so we proceeded to the analyses keeping all the participants included in the original sample.

## Effects of CR on Creativity

We performed a series of linear regressions, using CR proxies (i.e., WAIS-IV subtests scores, years of completed education, and frequency of involvement in leisure activities) as predictors and the scores derived from the creative tasks as dependent variables. Least squared regression was weighted by age. Overall CR proxies were able to predict performance in the creative tasks, but different proxies explained different aspects of the performance (see **Table 1**).

To investigate the possible specific effects of different types of leisure activities, we computed frequencies scores of different

categories of leisure activities: creative (i.e., playing music, making art, attending arts events, etc.), cognitive (i.e., playing crosswords, using technology to look up information, taking care of family budget, etc.), physical (i.e., exercising, gardening, practicing a sport, etc.), and social (i.e., being part of a club, taking care of a family members, attending social events, etc.).

Then we run the same regression analysis, using the categories of leisure activities as predictors and the scores of the cognitive tasks as dependent variables. Least squared regression was weighted by age. Results are reported in **Table 2**.

**TABLE 1 |** Liner Regression Model considering the effects of CR proxies on creative performance.

	<i>b</i>	<i>SEb</i>	$\beta$
<b>ACRONYM FLUIDITY</b>			
Constant	-15.30	2.77	
Similarities	0.49	0.08	0.53***
Digital span 1	0.26	0.21	0.09
Digital span 2	-0.30	0.17	-0.12
Vocabulary	0.13	0.07	0.22
Years of education	0.05	0.15	0.03
Frequency of leisure Activities	3.76	0.50	0.45***
$R^2 = 0.78; p < 0.001;$ *** $p < 0.001$			
<b>ACRONYM ORIGINALITY</b>			
Constant	-18.35	2.11	
Similarities	0.45	0.06	0.49***
Digital span 1	0.45	0.16	0.15**
Digital span 2	-0.45	0.13	-0.18**
Vocabulary	0.21	0.06	0.36***
Years of education	0.00	0.11	0.00
Frequency of leisure Activities	3.55	0.38	0.43***
$R^2 = 0.87; p < 0.001;$ ** $p < 0.01$ ; *** $p < 0.001$			
<b>ALTERNATIVE USE—FLUIDITY</b>			
Constant	-2.37	2.67	
Similarities	0.15	0.08	0.17
Digital span 1	-0.98	0.20	-0.34***
Digital span 2	0.23	0.16	0.10
Vocabulary	0.25	0.07	0.44**
Years of education	0.48	0.14	0.29**
Frequency of leisure Activities	1.09	0.49	0.14*
$R^2 = 0.77; p < 0.001;$ * $p < 0.05$ ; ** $p < 0.01$ ; *** $p < 0.001$			
<b>ALTERNATIVE USE—ORIGINALITY</b>			
Constant	-5.59	2.98	
Similarities	0.37	0.09	0.45***
Digital span 1	-0.46	0.22	-0.73*
Digital span 2	0.01	0.18	0.01
Vocabulary	0.12	0.08	0.22
Years of education	0.29	0.16	0.19
Frequency of leisure Activities	1.40	0.55	0.19**
$R^2 = 0.67; p < 0.001;$ * $p < 0.05$ ; ** $p < 0.01$ ; *** $p < 0.001$			

When examining the creative performance in response to the acronym task, practicing creative activities improved the task performance, positively affecting both fluency and originality, where no type of other leisure activities apparently influenced creativity. The alternative tasks task returned a different picture. Fluidity was positively affected by performing creative tasks and by being physically active and was negatively affected by being engaged in cognitive activities. Originality was positively affected by being physically active.

## Effects of Creative Activities on CR

We also investigated the possible effects of activating creativity throughout the life on the different proxies of CR. Participants' responses to section 3 (Occupation history) of the CoRe-T were analyzed and different occupations were coded as creative or non-creative. Jobs were coded as creative if they were not routine tasks, required constant flexibility of thoughts, changes of perspective, and creation of new and innovative ideas/solutions. Cases of disagreement were discussed and resolved case by

case by the two researchers who were in charge of all scoring procedures. Examples of creative jobs were: manager of an art gallery, musician, college professor, and high school teacher (these last examples have been discussed but ultimately defined as creative because of the necessity of constantly vary course contents or class activities and adopt different perspectives when interacting with different students). Examples of non-creative jobs were: lab technician, post office employer or director, bank teller. An overall evaluation (creative job vs. non-creative job) was computed for each participant, considering the prevalent type of occupations and the numbers of years that each occupation was covered by the participant.

We performed a MANOVA considering CR proxies as dependent variables, the main type of occupation (creative vs. non-creative) as a fixed factor, and age as a covariate. Means scores and standard deviations are reported in **Table 3**.

Having been employed in creative jobs appears to have a direct effect on several proxies of CR. The factors more affected were Similarities [ $F_{(1, 69)} = 35.40$ ;  $p < 0.001$ ;  $\eta^2 = 0.34$ ] and Vocabulary [ $F_{(1, 69)} = 35.69$ ;  $p < 0.001$ ;  $\eta^2 = 0.34$ ], followed by Reverse Digit Span [ $F_{(1, 69)} = 9.12$ ;  $p < 0.01$ ;  $\eta^2 = 0.12$ ] and frequency of leisure activities [ $F_{(1, 69)} = 7.14$ ;  $p < 0.01$ ;  $\eta^2 = 0.09$ ]. Performance on the Direct Digit Span task was the only proxy not affected by the occupation type.

Since the complexity of occupation, as discussed in the Introduction, has been reported as a factor influencing CR, we also run a more fine analysis, considering the level of complexity of occupation as well as the creative components of it. To do so, we categorized the occupations according to level of complexity by referring to the description of the specific position each individual reported in section 3 of the CoRe-T. We divided jobs into 4 categories: low complexity and not creative (e.g., post office employer); low complexity and creative (e.g., nanny); high complexity and not creative (e.g., director of a car rental agency); high complexity and creative (e.g., director of a music series). We run another ANOVA, considering CR proxies as dependent variables, the main type of occupation (divided into the four levels described above) as a fixed factor, and age as a covariate. Means scores and standard deviations are reported in **Table 4**.

**TABLE 2 |** Liner Regression Model considering the effects of different categories of leisure activities on creative performance.

	<i>b</i>	<i>SEb</i>	$\beta$
<b>ACRONYM FLUIDITY</b>			
Constant	-3.29	2.32	
Creative activities	3.72	1.05	0.60***
Cognitive activities	0.42	0.80	0.05
Physical activities	-0.49	0.61	-0.08
Social activities	0.59	0.80	0.11

$R^2 = 0.47$ ;  $p < 0.001$ ;  
\*\*\* $p < 0.001$

	<i>b</i>	<i>SEb</i>	$\beta$
<b>ACRONYM ORIGINALITY</b>			
Constant	-2.84	2.28	
Creative activities	3.72	1.05	0.60***
Cognitive activities	0.42	0.80	0.05
Physical activities	-0.49	0.61	-0.08
Social activities	0.59	0.80	0.11

$R^2 = 0.47$ ;  $p < 0.001$ ;  
\*\*\* $p < 0.001$

	<i>b</i>	<i>SEb</i>	$\beta$
<b>ALTERNATIVE USE—FLUIDITY</b>			
Constant	6.53	2.69	
Creative activities	2.48	1.22	0.42*
Cognitive activities	-1.96	0.93	-0.26*
Physical activities	1.61	0.71	0.28*
Social activities	-0.34	0.92	-0.07

$R^2 = 0.23$ ;  $p < 0.01$ ;  
\* $p < 0.05$

	<i>b</i>	<i>SEb</i>	$\beta$
<b>ALTERNATIVE USE—ORIGINALITY</b>			
Constant	3.05	2.57	
Creative activities	0.74	1.17	0.14
Cognitive activities	-0.78	0.89	-0.11
Physical activities	1.60	0.68	0.30*
Social activities	0.61	0.87	0.13

$R^2 = 0.18$ ;  $p < 0.01$ ;  
\* $p < 0.05$

**TABLE 3 |** Mean scores and standard deviation for the different cr proxies according to occupation creativity level.

CR Proxy	Occupation creativity level	Mean	Std. Deviation
Similarities	Non-creative	14.56	5.75
	Creative	21.56	3.06
Digit Span Direct	Non-creative	10.33	2.39
	Creative	10.67	1.07
Digit Span Reverse	Non-creative	7.00	2.02
	Creative	8.56	2.14
Vocabulary	Non-creative	30.22	8.11
	Creative	41.33	6.20
CR on the base of frequency of LA	Non-creative	2.67	0.61
	Creative	3.11	0.60

**TABLE 4 |** Mean scores and standard deviation for the different CR proxies according to occupation creativity and complexity level.

CR Proxy	Occupation creativity and complexity levels	Mean	Std. Deviation
Similarities	Low complexity and not creative	13.80	6.20
	Low complexity and creative	25.00	1.07
	High complexity and not creative	15.50	5.19
	High complexity and creative	20.57	2.71
Digit span direct	Low complexity and not creative	9.80	2.28
	Low complexity and creative	10.00	0.00
	High complexity and not creative	11.00	2.42
	High complexity and creative	10.86	1.14
Digit span reverse	Low complexity and not creative	7.60	1.23
	Low complexity and creative	7.00	1.07
	High complexity and not creative	6.25	2.57
	High complexity and creative	9.00	2.18
Vocabulary	Low complexity and not creative	29.00	6.99
	Low complexity and creative	38.50	4.81
	High complexity and not creative	31.75	9.33
	High complexity and creative	42.14	6.38
Cognitive reserve on the base of frequency of LA	Low complexity and not creative	3.02	0.46
	Low complexity and creative	3.62	0.34
	High complexity and not creative	2.23	0.49
	High complexity and creative	2.97	0.58

The between-subject test highlighted similar main effects as the ones emerged from the first ANOVA. They type of job influenced the performance on Similarities test [ $F_{(3, 67)} = 15.86$ ;  $p < 0.001$ ;  $\eta^2 = 0.42$ ], Reverse Digit Span [ $F_{(3, 67)} = 6.95$ ;  $p < 0.001$ ;  $\eta^2 = 0.24$ ], Vocabulary [ $F_{(3, 67)} = 13.50$ ;  $p < 0.001$ ;  $\eta^2 = 0.36$ ], and Frequency of Leisure Activities [ $F_{(3, 67)} = 13.28$ ;  $p < 0.001$ ;  $\eta^2 = 0.37$ ]. No effect of the performance of the Direct Digit Span emerged [ $F_{(3, 67)} = 1.97$ ;  $p = 0.13$ ;  $\eta^2 = 0.08$ ].

A pairwise comparison, performed using Bonferroni correction, showed significant differences among the levels of the independent variable. Mean differences and standard errors are reported in **Table 5**. Creativity levels rather than complexity were reliable predictors of the levels of CR proxies. Individuals with creative occupation performed better in the Similarities and Vocabularies tests than individuals who had non-creative occupations, and this was true regardless of the complexity of the job. The same was true for the frequency of leisure activities: Participants who had creative jobs reported to be involved more frequently in different types of leisure activities. No significant difference emerged for the Direct Digit Span test. Only creative jobs characterized by high complexity allowed individuals to score better in the Reverse Digit Span test.

## DISCUSSION AND CONCLUSIONS

The present study aimed at exploring the relationships between CR and creativity. Literature about the role of different proxies used to assess CR highlighted that most of them share the

common characteristic of allowing the aging population to use alternative strategies of thought. This would help the elder to better cope with age-related brain injuries. Skills required for using these alternative strategies appear to be similar to the ones that characterize the creative process. To be more precise, accessing and applying alternative strategies require an individual to be able to keep an open mind, to establish new and unusual relationships, and to change the perspective when required. These mental operations have been used to define a comprehensive creative process (Antonietti and Colombo, 2013, 2016).

Starting from these similarities, we were expecting to find a positive relationship between CR and creativity. We explored both a direct and reverse relationship, and in both cases our hypothesis was confirmed.

We started by exploring the effects of the proxies most commonly used in literature to assess CR and explore their possible influence on the performance of creative tasks (verbal creativity). Results highlighted that the proxies influenced performance of creative tasks but in different ways. Individual cognitive abilities, as measured by the WAIS subtests, had significant effects on specific aspects of the creative tasks, depending on the ability that was required the most to provide good answers. For example, higher scores in the Vocabulary subtest led participants to be more original when inventing new synonyms and produce more alternative uses of empty water bottles. This result is coherent with the definition of CR as the capacity to recruit different networks, optimizing the performance, and reflecting the use of alternate cognitive strategies as needed by the task at hand (Roldán-Tapia et al., 2012). This finding also confirms the results by Palmiero et al. (2016), who found that verbal creativity (the same that we assessed using the CoRe-T) specifically predicts the level of CR. Interestingly, the performance in the Digit Span test showed often a negative relationship with the creative performance. It is likely that individuals were not relying so much on the use of working memory while facing creative tasks. This result is coherent to some extent with the results from Arcara et al. (2017), who reported that a general CR index did not predict abstract math ability. Even if the Digit Span test is not a math test *per se*, it requires the activation of neural networks related to mathematical thinking, together with working memory (Raghubar et al., 2010). It is worth noticing that literature showed a positive relationship between working memory and creative performance (e.g., De Dreu et al., 2008, 2012; Takeuchi et al., 2011), but it looks like our participants preferred relying on processes more closely associated with long-term memory (i.e., their vocabulary skills). Since most of the studies reported in literature used a younger population as a sample, this could be an interested age-related effect to be further investigated in future studies.

The frequency of leisure activities was the proxy that had always a significant positive effect on the creative performance. This could have been because diversifying everyday leisure activities helps people to generate many different ideas and to change the mental perspective frequently. To support this possible reading of the finding reported above, we investigated

**TABLE 5 |** Pairwise comparison; mean difference and se for the different CR proxies according to occupation creativity and complexity level.

			Mean Difference	Std. Error	p
Similarities	Low complexity and not creative	Low complexity and creative	-11.03	1.83	<0.001
		High complexity and not creative	-2.12	1.49	0.95
		High complexity and creative	-6.47	1.29	<0.001
	Low complexity and creative	Low complexity and not creative	11.03	1.83	<0.001
		High complexity and not creative	8.91	1.93	<0.001
		High complexity and creative	4.56	1.75	0.07
	High complexity and Not creative	Low complexity and not Creative	2.12	1.49	0.95
		Low complexity and creative	-8.91	1.93	<0.001
		High complexity and creative	-4.35	1.43	0.02
	High complexity and creative	Low complexity and not creative	6.47	1.29	<0.001
		Low complexity and creative	-4.56	1.76	0.07
		High complexity and not creative	4.35	1.43	0.02
Digit Span	Low complexity and not creative	Low complexity and creative	-0.18	0.76	1.00
		High complexity and not creative	-1.24	0.620	0.29
		High complexity and creative	-1.03	0.54	0.36
	Low complexity and creative	Low complexity and not creative	0.18	0.76	1.00
		High complexity and not creative	-1.06	0.80	1.00
		High complexity and creative	-0.844	0.730	1.00
	High complexity and not creative	Low complexity and not creative	1.24	0.62	0.29
		Low complexity and creative	1.06	0.80	1.00
		High complexity and creative	0.22	0.59	1.00
	High complexity and creative	Low complexity and not creative	1.03	0.54	0.36
		Low complexity and creative	0.84	0.73	1.00
		High complexity and not creative	-0.22	0.59	1.00
Digit Span Reverse	Low complexity and not creative	Low complexity and creative	0.58	0.83	1.00
		High complexity and not creative	1.39	0.67	0.26
		High complexity and creative	-1.43	0.59	0.10
	Low complexity and creative	Low complexity and not creative	-0.5859	0.8319	1.00
		High complexity and not creative	0.8029	0.8729	1.00
		High complexity and creative	-2.01	0.80	0.08
	High complexity and not creative	Low complexity and not creative	-1.39	0.67	0.26
		Low complexity and creative	-0.80	0.87	1.00
		High complexity and creative	-2.81	0.65	<0.001
	High complexity and creative	Low complexity and not creative	1.43	0.59	0.10
		Low complexity and creative	2.01	0.80	0.08
		High complexity and not creative	2.81	0.65	<0.001
Vocabulary	Low complexity and not creative	Low complexity and creative	-9.14	2.91	0.01
		High complexity and not creative	-3.64	2.36	0.77
		High complexity and creative	-12.51	2.05	<0.001
	Low complexity and creative	Low complexity and not creative	9.14	2.91	0.01
		High complexity and not creative	5.50	3.06	0.45
		High complexity and creative	-3.37	2.79	1.00
	High complexity and not creative	Low complexity and not creative	3.64	2.36	0.77
		Low complexity and creative	-5.50	3.06	0.46
		High complexity and creative	-8.87	2.28	0.01
	High complexity and creative	low complexity and not creative	12.51	2.05	<0.001
		low complexity and creative	3.36	2.79	1.00
		high complexity and not creative	8.87	2.28	0.01

(Continued)

TABLE 1 | Continued

			Mean Difference	Std. Error	p
Cognitive Reserve on the base of frequency of LA	Low complexity and not creative	Low complexity and creative	-0.58	0.21	0.05
		High complexity and not creative	0.76	0.17	<0.001
		High complexity and creative	0.07	0.15	1.00
	Low complexity and creative	Low complexity and not creative	0.58	0.21	0.05
		High complexity and not creative	1.35	0.22	<0.001
		High complexity and creative	0.66	0.20	0.01
	High complexity and not creative	Low complexity and not creative	-0.76	0.17	<0.001
		Low complexity and creative	-1.35	0.22	<0.001
		High complexity and creative	-0.69	0.17	0.01
	High complexity and creative	Low complexity and not creative	-0.07	0.15	1.00
		Low complexity and creative	-0.66	0.20	0.01
		High complexity and not creative	0.69	0.17	0.01

the specific role of different categories of leisure activities to test if we could find a specific effect due to different types of leisure activities people were involved in. Results highlighted that, while (as it could be expected) it was the frequency of engaging in creative activities that predicts best the performance in the acronym task, the performance of the alternative uses task was significantly influenced by the frequency of several types of creative activities. Fluency was significantly predicted by all categories other than by social activities. Practicing cognitive activities showed a negative but significant relationship with the number of alternative uses suggested by participants. Someone might argue that there is something about engaging in creative activities that make individuals slightly more conservative in their choice of responses to divergent thinking tasks. Being more involved in creative activities should elicit the opposite behavior since individuals should learn that being free to generate ideas can be useful and productive, and hence face tasks like the Alternative Uses with this same perspective. Following this line of thoughts, it is quite interesting to remark that the originality of uses was positively related to the frequency of practicing physical activity. Being involved in a variety of leisure activities might induce people to figure out alternative uses for objects since these individuals are probably exposed to more and more differentiated situations. The specific link between practicing physical activities and being more original in alternative uses task can be partially explained by referring to existing literature reporting a direct positive relationship between practicing physical activities and increasing creative thinking, at least in children (for a review see Best, 2010; for a meta-analysis see Fedewa and Ahn, 2011). Future studies should explore better this relationship in an older population. The only review on the topic (Angevaren et al., 2008) explores mainly the effect of cardiovascular activities on cognitive function in the elderly population. From our data, it is clear that most of the spontaneous physical activities reported by our participants were not cardiovascular, but more moderate, if constant. The fact that we found a specific strong effect on the originality of answers in our sample could also be explained by observing that gardening was one of the activities included in

this category of leisure activities. Empty plastic bottles could be used in many different ways while gardening. Specific gardens or project might lead to inventing different uses according to specific needs, and this might help to explain this result. Exploring this effect using a different version of the alternative uses tasks could help clarifying this point.

We also explored the possible effect of being involved in a creative job over time on CR. Again, we were expecting a positive effect, given the overlapping between the cognitive functions involved in cognitive processes and the ones that promote CR. The type of job (creative vs. non-creative) influenced almost all the proxies of CR (both cognitive, as assessed by the WAIS subtests, and behavioral, as reflected by the frequency of being involved in leisure activities). The most interesting finding emerged when comparing creative and non-creative job while taking into consideration the complexity of the position. This more refined analysis was performed on the basis of literature findings suggesting that job complexity can influence CR (Stern et al., 1994; Richards and Sacker, 2003; Staff et al., 2004). Our findings showed that the creative component, more than the complexity *per se*, affects CR. This result has a direct link with our main research question, which was focused on the similarities between the mechanisms that have been hypothesized to be at the basis of CR and to promote it and the ones that have been supposed to be the common mental functions underlying creative thinking.

The study presents some limitations that could be addressed by future research. First of all our sample was recruited only from one State, which is characterized by a very rural environment and has a high percentage of active elders. This might have affected the results. More data from different environments should be collected. A second limitation is the size of our sample. Even if the results always reached acceptable power levels, the sample *per se* was quite small. Our results should be replicated with a larger sample. The current results should be seen as a first promising step. Our participants also had high or medium SES: Considering a population from a low SES could promote a better understanding of CR and could help reaching

conclusions that could be generalized. We also decided not use standardized creativity tests, but adopt alternative versions of creative tasks. Even if this choice can be read as a limitation, using alternative versions of standard tasks is a relatively common practice (Guilford, 1967; Torrance, 1990; Colombo et al., 2015). We decided to pick this route, which allows us to circumvent copyright issues, because we aim at having the CoRe-T available to use as a standalone test for CR that includes creative tasks.

This study, though preliminary mainly be because of the limited sample size, highlighted some new aspects that can help clarify the specific nature of the cognitive mechanism underlying CR, especially its close relationship with creative thinking and the level of creativity of previous occupations, a link that has not been explored so far, to our knowledge. This might be useful in devising program to increase CR by focusing on creative tasks, which could be perceived as engaging and motivating for the elderly population.

Our data also offer suggestions on an alternative way to assess CR. Creative tasks could be added as proxies to assess CR. This has been already suggested in literature (see Palmiero et al., 2016) but our data allow to be even more detailed in suggesting how to include creativity in a CR assessment. A combination of creative

tasks and a focus on lists of leisure activities that could be easily categorized to examine the frequency of creative vs. cognitive, vs. physical, vs. social activities could be beneficial both in clinical and experimental settings. More data from an instrument like the CoRe-T, used in the current study, could help researchers moving in this direction.

## ETHICS STATEMENT

This study was carried out in accordance with the recommendations of APA ethical guidelines with written informed consent from all subjects. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the Champlain College IRB Committee.

## AUTHOR CONTRIBUTIONS

BC designed the research, helped with data collection and coding, analyzed the data, wrote the paper. AA helped to design the research, discussed the findings, revised the paper. BD helped designing data collection, collecting, and coding the data.

## REFERENCES

- Aartsen, M. J., Smits, C. H., van Tilburg, T., Knipscheer, K. C., and Deeg, D. J. (2002). Activity in older adults: cause or consequence of cognitive functioning? A longitudinal study on everyday activities and cognitive performance in older adults. *J. Gerontol. Ser. B. Psychol. Sci. Soc. Sci.* 57, 153–162. doi: 10.1093/geronb/57.2.P153
- Angevaren, M., Aufdemkampe, G., Verhaar, H. J., Aleman, A., and Vanhees, L. (2008). Physical activity and enhanced fitness to improve cognitive function in older people without known cognitive impairment. *Cochrane Database Syst. Rev.* 3, 2–96. doi: 10.1002/14651858.CD005381.pub3
- Antonietti, A., and Colombo, B. (2013). “Three creative operations,” in *Creativity, Talent Development, and Excellence*, ed A.-G. Tan (New York, NY: Springer), 13–26.
- Antonietti, A., and Colombo, B. (2016). “Creative cognition: How culture matters” in *Handbook of Creativity and Culture*, ed V. Glaveanu (Basingstoke: Palgrave MacMillan), 101–124.
- Arcara, G., Mondini, S., Bisso, A., Palmer, K., Meneghello, F., and Semenza, C. (2017). The relationship between cognitive reserve and math abilities. *Front. Aging Neurosci.* 9:429. doi: 10.3389/fnagi.2017.00429
- Beatty, R. E., Benedek, M., Kaufman, S. B., and Silvia, P. J. (2015). Default and executive network coupling supports creative idea production. *Sci. Rep.* 5:10964. doi: 10.1038/srep10964
- Bennett, D. A. (2006). Postmortem indices linking risk factors to cognition: results from the religious order study and the memory and aging project. *Alzheimer Disease Assoc. Disord.* 20, S63–S68. doi: 10.1097/00002093-200607001-00009
- Bennett, D. A., Schneider, J. A., Tang, Y., Arnold, S. E., and Wilson, R. S. (2006). The effect of social networks on the relation between Alzheimer’s disease pathology and level of cognitive function in old people: a longitudinal cohort study. *Lancet Neurol.* 5, 406–412. doi: 10.1016/S1474-4422(06)70417-3
- Best, J. R. (2010). Effects of physical activity on children’s executive function: contributions of experimental research on aerobic exercise. *Develop. Rev.* 30, 331–351. doi: 10.1016/j.dr.2010.08.001
- Chrysikou, E. G., Hamilton, R. H., Coslett, H. B., Datta, A., Bikson, M., and Thompson-Schill, S. L. (2013). Noninvasive transcranial direct current stimulation over the left prefrontal cortex facilitates cognitive flexibility in tool use. *Cogn. Neurosci.* 4, 81–89. doi: 10.1080/17588928.2013.768221
- Colombo, B., Balzarotti, S., and Greenwood, A. (2018). Using a reminiscence based approach to investigate the cognitive reserve of healthy aging population. *Clin. Gerontol.* 5, 1–13. doi: 10.1080/07317115.2018.1447526
- Colombo, B., Bartesaghi, N., Simonelli, L., and Antonietti, A. (2015). The combined effects of neurostimulation and priming on creative thinking. A preliminary tDCS study on dorsolateral prefrontal cortex. *Front. Human Neurosci.* 9:403. doi: 10.3389/fnhum.2015.00403
- Corral, M., Rodriguez, M., Amenedo, E., Sanchez, J. L., and Diaz, F. (2006). Cognitive reserve, age, and neuropsychological performance in healthy participants. *Dev. Neuropsychol.* 29, 479–491. doi: 10.1207/s15326942dn2903\_6
- De Dreu, C. K., Baas, M., and Nijstad, B. A. (2008). Hedonic tone and activation level in the mood-creativity link: toward a dual pathway to creativity model. *J. Pers. Soc. Psychol.* 94, 739–756. doi: 10.1037/0022-3514.94.5.739
- De Dreu, C. K., Nijstad, B. A., Baas, M., Wolsink, I., and Roskes, M. (2012). Working memory benefits creative insight, musical improvisation, and original ideation through maintained task-focused attention. *Pers. Soc. Psychol. Bull.* 38, 656–669. doi: 10.1177/0146167211435795
- Fedewa, A. L., and Ahn, S. (2011). The effects of physical activity and physical fitness on children’s achievement and cognitive outcomes: a meta-analysis. *Res. Q. Exerc. Sport* 82, 521–535. doi: 10.1080/02701367.2011.10599785
- Fratiglioni, L., Wang, H. X., Ericsson, K., Maytan, M., and Winblad, B. (2000). Influence of social network on occurrence of dementia: a community-based longitudinal study. *Lancet* 355, 1315–1319. doi: 10.1016/S0140-6736(00)02113-9
- Guilford, J. P. (1967). *The Nature of Human Intelligence*. New York, NY: McGraw Hill.
- Iannello, P., Colombo, B., and Antonietti, A. (2014). “Non-invasive brain stimulation techniques in the study of intuition,” in *Handbook of Research Methods on Intuition*, ed M. Sinclair (Northampton, MA: Edward Elgar Publishers), 130–143.
- Manenti, R., Cotelli, M., and Miniussi, C. (2011). Successful physiological aging and episodic memory: a brain stimulation study. *Behav. Brain Res.* 216, 153–158. doi: 10.1016/j.bbr.2010.07.027
- Manly, J. J., Schupf, N., Tang, M. X., and Stern, Y. (2005). Cognitive decline and literacy among ethnically diverse elders. *J. Geriatr. Psychiatry Neurol.* 18, 213–217. doi: 10.1177/0891988705281868



- Manly, J. J., Touradj, P., Tang, M. X., and Stern, Y. (2003). Literacy and memory decline among ethnically diverse elders. *J. Clin. Exp. Neuropsychol.* 25, 680–690. doi: 10.1076/jcen.25.5.680.14579
- Mortimer, J. A., Snowdon, D. A., and Markesbery, W. R. (2003). Head circumference, education and risk of dementia: findings from the nun study. *J. Clin. Exp. Neuropsychol.* 25, 671–679. doi: 10.1076/jcen.25.5.671.14584
- Mousavi-Nasab, S. M., Kormi-Nouri, R., and Nilsson, L. G. (2014). Examination of the bidirectional influences of leisure activity and memory in old people: a dissociative effect on episodic memory. *Br. J. Psychol.* 105, 382–398. doi: 10.1111/bjop.12044
- Nucci, M., Mapelli, D., and Mondini, S. (2012). Cognitive Reserve Index questionnaire (CRIq): a new instrument for measuring cognitive reserve. *Aging Clin. Exp. Res.* 24, 218–226. doi: 10.3275/7800
- Oldrati, V., Colombo, B., and Antonietti, A. (2018). Combination of a short cognitive training and tDCS to enhance visuospatial skills: a comparison between online and offline neuromodulation. *Brain Res.* 1678, 31–39. doi: 10.1016/j.brainres.2017.10.002
- Oldrati, V., Patricelli, J., Colombo, B., and Antonietti, A. (2016). The role of dorsolateral prefrontal cortex in inhibition mechanism: a study on cognitive reflection test and similar tasks through neuromodulation. *Neuropsychologia* 91, 499–508. doi: 10.1016/j.neuropsychologia.2016.09.010
- Opdebeeck, C., Martyr, A., and Clare, L. (2016). Cognitive reserve and cognitive function in healthy older people: a meta-analysis. *Aging Neuropsychol. Cogn.* 23, 40–60. doi: 10.1080/13825585.2015.1041450
- Palmiero, M., Di Giacomo, D., and Passafiume, D. (2016). Can creativity predict cognitive reserve?. *J. Creat. Behav.* 50, 7–23. doi: 10.1002/jocb.62
- Raghubar, K. P., Barnes, M. A., and Hecht, S. A. (2010). Working memory and mathematics: a review of developmental, individual difference, and cognitive approaches. *Learn. Individ. Differ.* 20, 110–122. doi: 10.1016/j.lindif.2009.10.005
- Richards, M., and Sacker, A. (2003). Lifetime antecedents of cognitive reserve. *J. Clin. Exp. Neuropsychol.* 25, 614–624. doi: 10.1076/jcen.25.5.614.14581
- Roldán-Tapia, L., García, J., Cánovas, R., and León, I. (2012). Cognitive reserve, age, and their relation to attentional and executive functions. *Appl. Neuropsychol. Adult* 19, 2–8. doi: 10.1080/09084282.2011.595458
- Solé-Padullés, C., Bartrés-Faz, D., Junqué, C., Vendrell, P., Rami, L., Clemente, I. C., et al. (2009). Brain structure and function related to cognitive reserve variables in normal aging, mild cognitive impairment and Alzheimer's disease. *Neurobiol. Aging* 30, 1114–1124. doi: 10.1016/j.neurobiolaging.2007.10.008
- Staff, R. T., Murray, A. D., Deary, I. J., and Whalley, L. J. (2004). What provides cerebral reserve?. *Brain* 127, 1191–1199. doi: 10.1093/brain/awh144
- Stern, Y. (2002). What is cognitive reserve? Theory and research application of the reserve concept. *J. Int. Neuropsychol. Soc.* 8, 448–460. doi: 10.1017/S1355617702813248
- Stern, Y. (2006). Cognitive reserve and Alzheimer disease. *Alzheimer Dis. Assoc. Disord.* 20, 112–117. doi: 10.1097/01.wad.0000213815.20177.19
- Stern, Y. (2009). Cognitive reserve. *Neuropsychologia* 47, 2015–2028. doi: 10.1016/j.neuropsychologia.2009.03.004
- Stern, Y., Alexander, G. E., Prohovnik, I., and Mayeux, R. (1992). Inverse relationship between education and parietotemporal perfusion deficit in Alzheimer's disease. *Ann. Neurol.* 32, 371–375. doi: 10.1002/ana.410320311
- Stern, Y., Gurland, B., Tatemichi, T. K., Tang, M. X., Wilder, D., and Mayeux, R. (1994). Influence of education and occupation on the incidence of Alzheimer's disease. *J. Am. Med. Assoc.* 271, 1004–1010. doi: 10.1001/jama.1994.03510370056032
- Takeuchi, H., Taki, Y., Hashizume, H., Sassa, Y., Nagase, T., Nouchi, R., et al. (2011). Failing to deactivate: the association between brain activity during a working memory task and creativity. *Neuroimage* 55, 681–687. doi: 10.1016/j.neuroimage.2010.11.052
- Torrance, E. P. (1990). *Tests of Creative Thinking: Streamlined Scoring Guide—Figural and Verbal A and B*. Bensenville, IL: Scholastic Testing Service
- Wechsler, D. (2008). *Wechsler Adult Intelligence Scale—Fourth Edition (WAIS-IV)*. San Antonio, TX: NCS Pearson.
- Weinberger, A. B., Green, A. E., and Chryssikou, E. G. (2017). Using transcranial direct current stimulation to enhance creative cognition: interactions between task, polarity, and stimulation site. *Front. Hum. Neurosci.* 11:246. doi: 10.3389/fnhum.2017.00246
- Wilson, R. S., Bennett, D. A., Beckett, L. A., Morris, M. C., Gilley, D. W., Bienias, J. L., et al. (1999). Cognitive activity in older persons from a geographically defined population. *J. Gerontol. Ser. B. Psychol. Sci. Soc. Sci.* 54, 155–160. doi: 10.1093/geronb/54B.3.P155
- Wilson, R. S., Schneider, J. A., Arnold, S. E., Bienias, J. L., and Bennett, D. A. (2007). Conscientiousness and the incidence of Alzheimer disease and mild cognitive impairment. *Arch. Gen. Psychiatry* 64, 1204–1212. doi: 10.1001/archpsyc.64.10.1204

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## APPENDIX 1—LIST OF LEISURE ACTIVITIES ASSESSED USING THE CORE-T

Frequency of activity is based on an average week.

1	2	3	4	5
Rarely/Never				Often/Everyday
Activity			Frequency	Years
<b>Example: Playing Chess</b>			<b>4</b>	<b>2</b>
Reading (Magazines, Newspapers)				
Use of Technology (Cellphones, Computers)				
Use of Other Language				
Physical Exercise				
Bank Account Management				
Puzzles (Crossword, Word Search)				
Reading (Books, Novels)				
Music (Listening, Playing)				
Gardening				
Cooking				
Art (For self)				
Art (For Showcase)				
Social Based Clubs (Book Clubs, Knitting Club, Etc.)				
Taking Care of Others				
Taking Care of Pets				
Managing Family Budget				
Playing Sports				
Other:				



# What Do Spatial Distortions in Patients' Drawing After Right Brain Damage Teach Us About Space Representation in Art?

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The right cerebral hemisphere plays a crucial role in spatial cognition, spanning from perception of elementary features, such as location, color, line orientation or shape to representation of different spaces (3D space, allocentric, egocentric, face, personal, peri-personal, or imaginal). One important aspect of its contribution concerns the perception of space symmetry and the representation of objects and scenes, with reference to the midline or body axis. This representation results from a balance between spatial attention processes depending from the two hemispheres. Healthy participants tend to show a discrete deviation of the midline plane representation toward the left side, that is likely to result from the predominance of the activity of the right cerebral hemisphere, mainly oriented toward the contralateral side of space. The visuospatial abilities of the right hemisphere, especially for the representation of the midline plane are crucially engaged in painting and drawing processes in artists. Interestingly, the distortions created by painters of the Cubism period, characterized by an asymmetry of objects and body representations, a specific enlargement or reduction of parts of space, or even by complex distortions of 3D space are analogous to those classically reported in right-brain-damaged patients (unilateral spatial neglect, hyperschemata, constructional apraxia). Understanding the pathological mechanisms of these representation disorders provides meaningful information to apprehend visual artist creations and esthetic perception of space.

**Keywords:** space representation, neglect syndrome, hyperschemata, right hemisphere damage, egocentric representation

## INTRODUCTION

One popular distinction for the internal representations of the surrounding world in humans is between verbal and visuo-spatial dimensions (see, e.g., Struiksma et al., 2009). The former mainly depends on the left cerebral hemisphere which is involved in linguistic processes. The latter is mainly related to the activity of the right cerebral hemisphere, which plays a crucial role in spatial cognition, spanning from perception of elementary features, such as location, color, line orientation or shape to representation of different spaces (Devinsky, 2009; Koch et al., 2013; Zaidel, 2013; Gainotti, 2014; for reviews of different aspects of the processes related to the activity of the right

hemisphere, and to the disorders brought about by right hemispheric damage). However, these two types of representation are closely linked: for example, when reading the verbal description of a natural space, as for example the description of the Fontainebleau forest by Gustave Flaubert (1821/1880) in his famous novel entitled '*la vie sentimentale*', we can spontaneously create an inner visual image of the forest which contributes to reinforce the poetic dimension of the narration. In the same way, when looking at an oil-painting of the Fontainebleau forest made by a French painter of the Barbizon school, Camille Corot (1796/1875), in the same era, we could name and identify the different space parts of the image (see **Figure 1**). This distinction between two types of explicit space representation for perception – verbal and visuospatial – is also relevant for the clinical description of cognitive deficits due to focal damage of the brain, especially following a damage of the right hemisphere, where different deficits could be described. These deficits are evidenced in tasks of drawing from memory or by copy. They may be omissions,

additions or distortions of parts of the object or the entire object.

## SPATIAL DISTORTION AFTER RIGHT BRAIN LESION

One interesting feature of misrepresentation concerns the perception of size (and volume) and the midline axis (Milner and Harvey, 1995; Milner et al., 1998). These distortions can be characterized by a size reduction, up to a total omission, of the left part of an object drawn, as illustrated by the object-centered (or allocentric) deficit of left spatial neglect. Sometimes, an expansion of the right hand-side of the object drawn, when productive manifestations with graphic perseverations and/or hypergraphia are also present (Rusconi et al., 2002; Ronchi et al., 2009). This size (and volume) asymmetry may reflect the combination of two underlying disorders of the unilateral neglect syndrome: an ipsilesional bias of the orientation of spatial attention, and an



**FIGURE 1** | Two types of explicit (verbal and visuospatial) space representation: example of the Fontainebleau forest. Oil painting *La Forêt de Fontainebleau*, par Camille Corot (1833) – Reproduced from National Gallery of Art, Washington DC with permission. Verbal description (in French and in English) by Gustave Flaubert (1821/1880) in the novel "*la vie sentimentale*" 3ème partie chapitre III, page 483. "La diversité des arbres faisait un spectacle changeant. Les hêtres, à l'écorce blanche et lisse, entremêlaient leurs couronnes; des frênes courbaient mollement leurs glauques ramures; dans les cépées de charmes, des houx pareils à du bronze se hérissaient; puis venaient une file de minces bouleaux, inclinés dans des attitudes élégiaques; et les pins, symétriques comme des tuyaux d'orgue, en se balançant continuellement, semblaient chanter". "The variety of trees furnished a spectacle of the most diversified character. The beeches with their smooth white bark twisted their tops together. Ash trees softly curved their bluish branches. In the tufts of the hornbeams rose up holly stiff as bronze. Then came a row of thin birches, bent into elegiac attitudes; and the pine-trees, symmetrical as organ pipes, seemed to be singing a song as they swayed to and fro".

impaired building and/or exploration of internal representations of space (Bisiach et al., 1994; Vallar, 1998; Ricci et al., 2000, 2004; Rode et al., 2017).

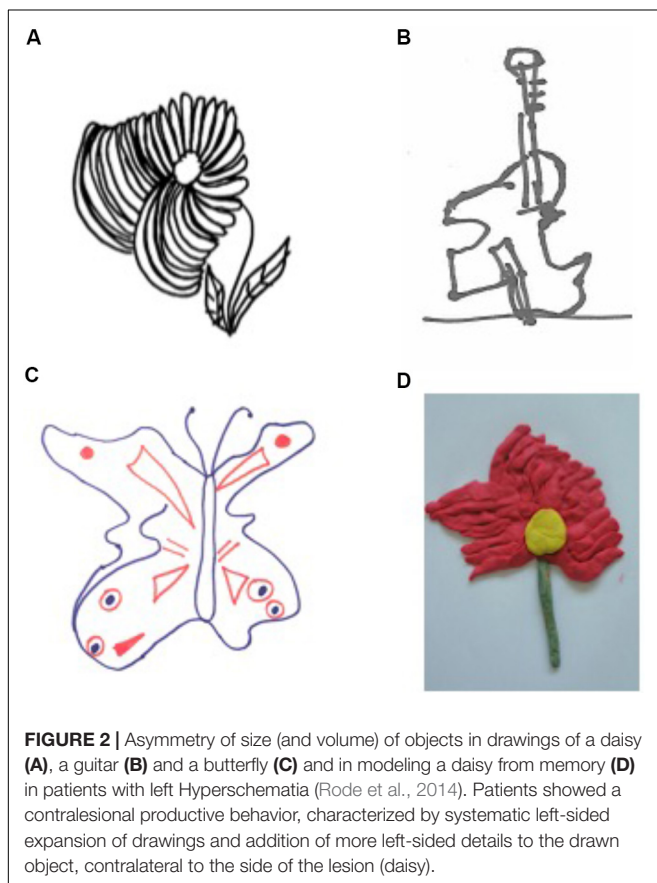
In others cases, this asymmetry of size (and volume) can be characterized by a systematic enlargement of the left-hand side of objects drawn from memory and by copy. This much infrequent deficit is observed in right-brain-damaged patients, regardless of the presence of the unilateral neglect syndrome, and has been termed “hyperschemata” (Rode et al., 2006). In a previous study, we have reported a series of 7 right-brain-damaged patients showing this spatial distortion for left extra-personal space. Hyperschemata can affect drawing of many different objects as such as a daisy, a tree, a butterfly, a man, a house or scene, the whole of an object, but also some parts of it (Rode et al., 2014). Hyperschemata can also be evidenced in three-dimensional (modeling), visuo-construction tasks, reinforcing the mainly spatial nature of the deficit (Rode et al., 2008) (see **Figures 2, 3**). The disorder remained unchanged when patients were asked to draw in a blindfold condition (Rode et al., 2006). Hyperschemata is most frequently contralateral to a lesion of the right hemisphere, and as for left spatial neglect, (Ronchi et al., 2014). Patients are not aware of the disorder.

Importantly, when patients were asked to perform an estimation of the two horizontal lengths of two rectangles, by perceptual matching, the comparison of the performances of seven patients with left hyperschemata and controls revealed

only a trend toward significance. However, the analysis of the individual scores of patients indicates that only four out of the seven patients showed a rightward overestimation; two patients performed as the control group of neurologically unimpaired participants, and one patient presented with an opposite pattern, namely a leftward overestimation. A disorder of perceptual estimation of lateral extent cannot account for hyperschemata in drawing, being possibly instead an associated deficit with no direct causal relationships with hyperschemata. Conversely, when patients were asked to reproduce the length of a horizontal segment (line extension task), the comparison of the performances of seven patients and controls showed a significant overextension in leftward line extension, while rightward line extension was within the normal range (see **Figure 4**).

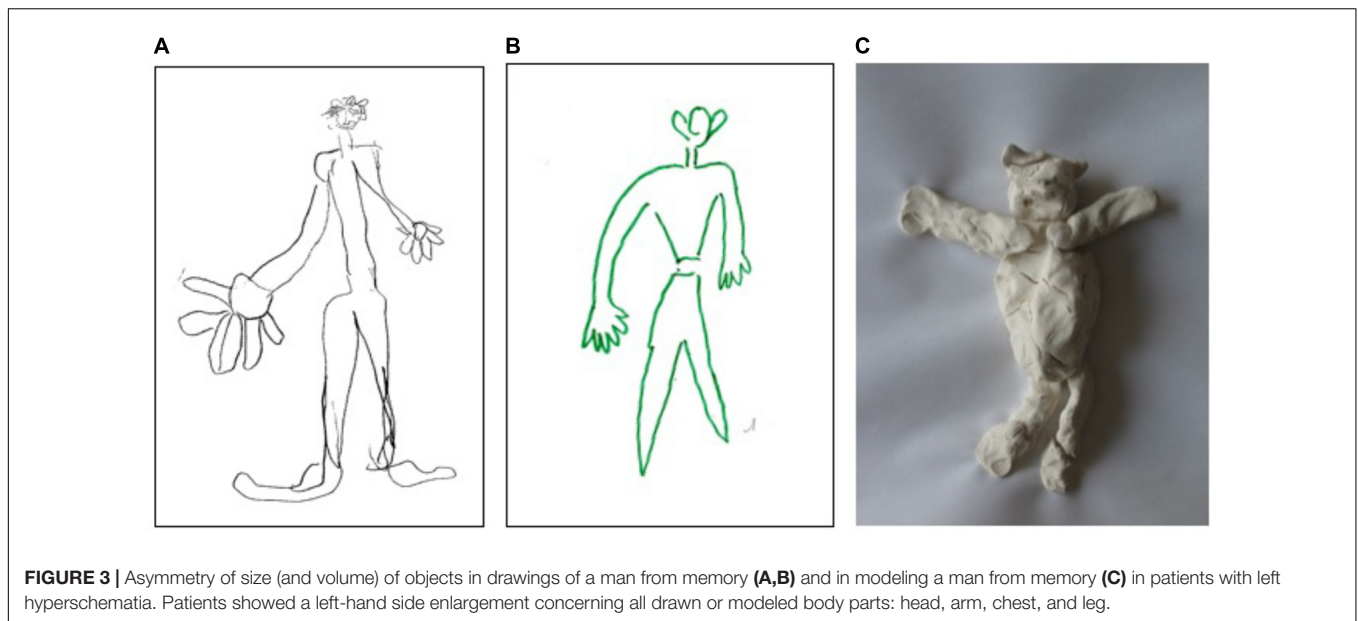
These findings suggested that hyperschemata occurs when operations (including planning and execution of motor acts in the left side of space) are required. Moreover they suggest that this non modality-specific distortion of space representation could be due to a lateral anisometry of the internal representation of space, namely: the spatial medium with a leftward relaxation (Rode et al., 2006, 2008). This leftward relaxation of spatial representation can be illustrated by this oil painting made by a right-brain-damaged patient (see **Figure 5** and also Rode et al., 2014).

More generally, a disproportionate enlargement of space representation may also affect bodily space. The first description was provided by the French otolaryngologist Pierre Bonnier (1905), based on the clinical observation of patients with vestibular disorders of peripheral origin (for an historical note see Vallar and Rode, 2009: see also Bonnier’s, 1905 book “Le vertige”). Bonnier reported that these patients may subjectively feel that their body or body-parts are disproportionately enlarged, and interpreted this disorder as a pathologic expansion of the spatial representation of the body or body parts (hyperschemata) (Vallar and Papagno, 2003). These feelings also resemble those reported by patients with macrosomatognosia or asomatognosia hallucinations, with patients referring the feeling that one or more parts of their body are disproportionately larger (Lhermitte and Tchehraz, 1937; Frederiks, 1969; Denes, 1989), after paroxysmal cerebral disorders such as epilepsy, migraine and hypnagogic hallucinations (Kew et al., 1998; Podoll and Robinson, 2002), somatosensory loss consecutive to a local anesthesia (Gandevia and Phegan, 1999; Paqueron et al., 2003), or a brainstem lesion (Rode et al., 2012). But, unlike hyperschemata for extra-personal space, patients are always aware of their deficit, suggesting different underlying neural and functional mechanisms and neural processes for disorders affecting the representation of the size (and the volume) of a portion of extra-personal or personal spaces.

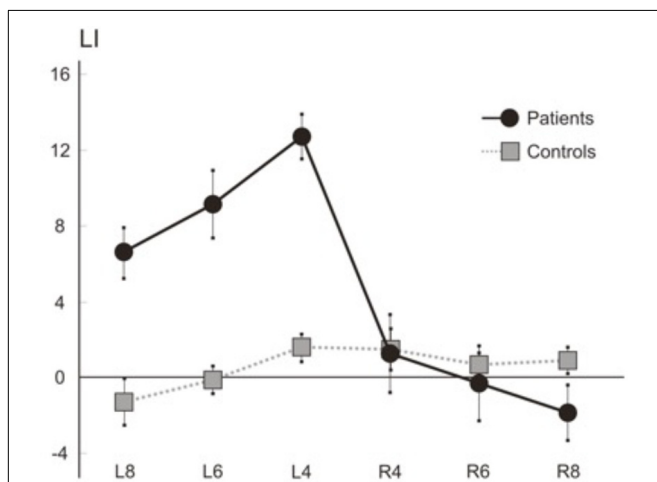


## SPATIAL DISTORTION IN PAINTING

The visuospatial abilities of the right hemisphere, especially those dedicated to the representation of size (and volume) and the midline plane, are crucially involved in painting and drawing



**FIGURE 3** | Asymmetry of size (and volume) of objects in drawings of a man from memory (A,B) and in modeling a man from memory (C) in patients with left hyperschematia. Patients showed a left-hand side enlargement concerning all drawn or modeled body parts: head, arm, chest, and leg.

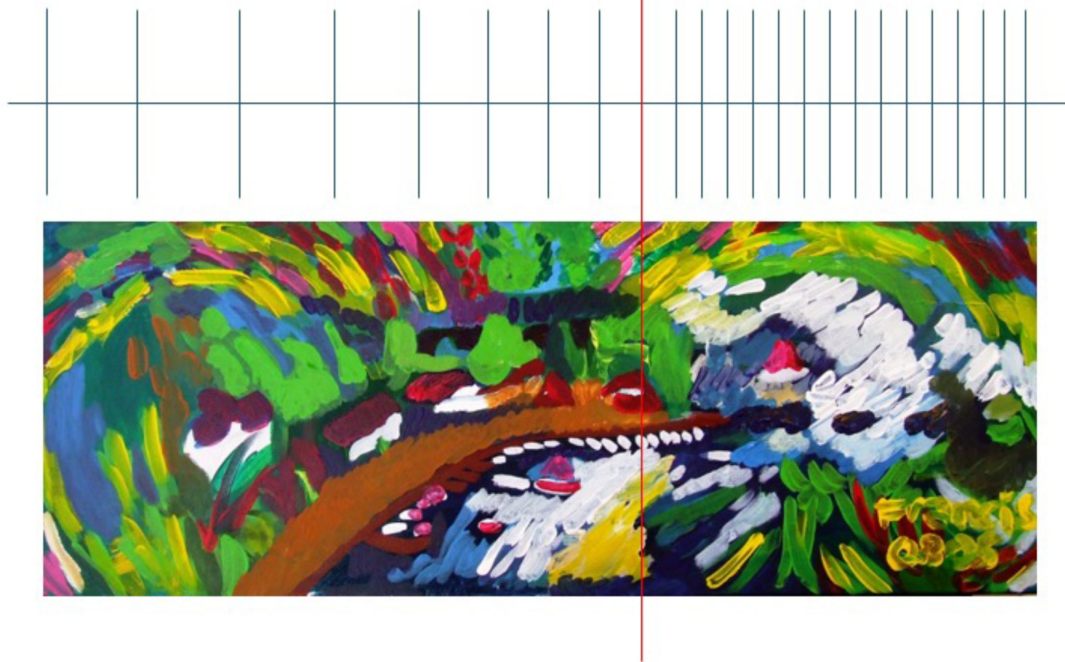


**FIGURE 4** | Line extension task. Mean (SEM) LIs of the seven right brain patients and six control participants for rightward (R) and leftward (L) extended lines (length: 4, 6, and 8 cm). The subject had to reproduce the length of a horizontal line in two rightward and leftward movement conditions. In each condition, the end of the line was aligned with the mid-sagittal plane of the body, and the patient reproduced the perceived length of the segment with a rightward or leftward extension. The stimuli were horizontal twenty-four black lines, 1 mm in width, with eight lines for three lengths (4, 6, and 8 cm). The length of the segment drawn by each subject on each trial was measured to the nearest mm. For the leftward extension of each line drawing, a following laterality index score (LI) was computed: Leftward extended length minus length of the right-sided line/leftward extended length plus length of the right-sided line  $\times$  100. For the rightward extension of each line drawing, the LI was: Rightward extended length minus length of the left-sided line/rightward extended length plus length of the left-sided line  $\times$  100. Positive/negative values of the LI indicate over/under-extension. Mean LIs were computed for the two directions of extension (rightward, leftward), and for three line lengths (4, 6, and 8 cm). All seven patients and six controls were tested. The Figure showed that 7 patients make a leftward overextension for three line lengths (4, 6, and 8 cm) while laterality scores for rightward extension do not differ from those of controls.

processes in artists. Many artists have been interested in the perception and representation of space from the Renaissance to modern times. At the beginning of the twentieth century (1907), Georges Braque and Pablo Picasso created a new artistic movement “Cubism,” which proposed a new approach to the perception and representation of space. Cubism was a revolution in painting and sculpture, and also influenced architecture, literature and music. Their goal was to deconstruct the Euclidean space and to materialize new alternative representations. This new space of cubists was characterized by a substitution of the frozen perspective of classical painters by a moving perspective. The discovery of cubists has been to show all objects from all sides at once, i.e. merging several viewpoints (Paulhan, 1993).

This deconstruction of space concerned the symmetry of size (and volume) and the representation of the plane midline. It can be illustrated by the oil painting intitled “Guitare et bouteille de marc sur une table” (Braque, 1930), which is a still life composed of several objects placed on a pedestal table. In addition to removing all coherent perspectives, the shape of the represented objects is asymmetrical; for example, for the guitar, the left half of the widened box is enlarged contrasting with an enlargement of the opposite part of the rose and the neck (see Figure 6A). These asymmetries of size and volume contribute to creating distortions in the representation of space and object, and thus materialize a new space in Braque’s own words: ‘*What attracted me greatly and which was the main direction of Cubism was the materialization of this new space that I felt. So I began to do mostly still-life, because in nature, there is a tactile space, I will say almost manual. It was this space that attracted me a lot. For this was the first Cubist painting, the search for space.*’ (G. Braque. (cited in: Vallier, 1954).

G. Braque also applied this new materialization of space to the bodily space. The oil painting untitled “Le Duo” painted in 1937, is an illustration. Braque represented two persons in front of an upright piano. The body of the woman sitting in front of the piano is unstructured; the bodily space is separated into two



**FIGURE 5** | Oil painting from memory of a right brain damaged patient.



**FIGURE 6** | Oil paintings of Georges Braque. “Guitare et bouteille de marc sur une table” (1930) – Reproduced from Cleveland Museum of Art with permission (A); “Le duo” (1937) – Reproduced from photo © Centre Pompidou, MNAM-CCI, Dist. RMN-Grand Palais/Philippe Migeat with permission (B).

asymmetrical halves: an enlarged left hemi-body seen from the front and in the light and a shrunken right hemi-body seen in profile and in the shadow (see **Figure 6B**). This deconstruction-reconstruction of the bodily space and the distortions that are attached to it allowed Georges Braque to represent all the possible perspectives of the bodily space on the same plane with a displacement of the middle axis of the body. These contribute to create a new esthetic representation of bodily space that Braque will further deepen in his subsequent works.

It is interesting to compare these distortions with the spatial distortions produced by patients with hyperschematia. In these two a priori remote situations, there is a loss of the symmetry of representation of size and volume and a displacement of the representation of the middle axis. In G. Braque, these distortions are the result of a creative and conscious process, while the “hyper schematic” ones result from an unconscious process as suggested by the patients’ unawareness of the disorder. Nevertheless, in

both situations, the result consists in the building up of an asymmetric representation of space and body midline.

However, these two types of distortions ask about the neural processes underlying the building of these representations of size, volume, and bodily space. These result from a balance between spatial attention processes of the two hemispheres. Healthy participants tend to show a discrete deviation of the midline plane representation toward the left side, reflecting the predominance of the right cerebral hemisphere activity for the contralateral space. This predominance is dramatically reduced after damage of the right hemisphere producing various distortions of extrapersonal and bodily space (Irving-Bell et al., 1999; Vallar and Bolognini, 2014). Hyperschematia constitutes an uncommon example of a distortion affecting size (and volume) and space. The disorder is most frequently contralateral to the right hemispheric lesion, as left spatial neglect. However, a few reports of ipsilesional right hyperschematia (Saj et al., 2011), and of ipsilesional right overextension (Bisiach et al., 1998) have been reported. Overall, these distortions suggest that the unbalance between the spatial processes of the two hemispheres is not confined to an ipsilesional orientational bias of spatial attention, that may account for the defective manifestations of spatial neglect but also concerns the representational dimension (Bisiach et al., 1996; Savazzi et al., 2007; Manfredini et al., 2013; Vallar and Bolognini, 2014).

Similar neural processes may be at work during artistic creation, reinforcing the idea that one intriguing aspect of the 'spatial brain' is its capability to construct non-Euclidian representations of extrapersonal and bodily spaces. This widening of the left side spatial representation can be seen as an alteration of the internal function of measuring distances, also called the metric in mathematics. The patient would then present

a non-constant right-to-left metric that would increase perceived distances in the contralateral side. Unconsciously, the patient distributes his painting homogeneously in a reference system whose calculation of distances undergoes a transformation gradient on a right / left axis. According to the same scheme, Cubist artists would make the voluntary choice, based on a more or less conscious evaluation of space, of modifying the metric of their drawing locally on its elements and thus produce multiple deformations depending on the position on the final work similarly as they do to encode depth in their paintings.

## DISCLOSURE

All authors have full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

## AUTHOR CONTRIBUTIONS

GR designed the work acquired, analyzed, did interpretation of data for the work, and drafted the work. GV and YR did interpretation of data for the work and revised the work critically for important intellectual content. EC revised the work critically for important intellectual content. PR analyzed data for the work and revised the work critically for important intellectual content.

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## REFERENCES

- Bisiach, E., Pizzamiglio, L., Nico, D., and Antonucci, G. (1996). Beyond unilateral neglect. *Brain* 119, 851–857.
- Bisiach, E., Ricci, R., and Neppi Modona, M. N. (1998). Visual awareness and anisometry of space representation in unilateral neglect: a panoramic investigation by means of a line extension task. *Conscious. Cogn.* 7, 327–355.
- Bisiach, E., Rusconi, M. L., Peretti, V. A., and Vallar, G. (1994). Challenging current accounts of unilateral neglect. *Neuropsychologia* 32, 1431–1434.
- Bonnier, P. (1905). L'aschématie. *Rev. Neurol.* 13, 605–609.
- Denes, G. (1989). "Disorders of body awareness and body knowledge," in *Handbook of Neuropsychology*, eds F. Boller and J. Grafman (Amsterdam: Elsevier), 207–228.
- Devinsky, O. (2009). Delusional misidentifications and duplications: right brain lesions, left brain delusions. *Neurology* 6, 80–87.
- Frederiks, J. A. M. (1969). "Disorders of the body schema," in *Handbook of Clinical Neurology. Disorders of Speech, Perception and Symbolic Behaviour*, eds P. J. Vinken and G. W. Bruyn (Amsterdam: North Holland), 207–240.
- Gainotti, G. (2014). Why are the right and left hemisphere conceptual representations different? *Behav. Neurol.* 2014:603134. doi: 10.1155/2014/603134
- Gandevia, S. C., and Phegan, C. M. (1999). Perceptual distortions of the human body image produced by local anaesthesia, pain and cutaneous stimulation. *J. Physiol.* 514, 609–616.
- Irving-Bell, L., Small, M., and Cowey, A. (1999). A distortion of perceived space in patients with right-hemisphere lesions and visual hemineglect. *Neuropsychologia* 37, 919–925.
- Kew, J., Wright, A., and Halligan, P. W. (1998). Somesthetic aura: the experience of "Alice in Wonderland". *Lancet* 351:1934.
- Koch, G., Veniero, D., and Caltagirone, C. (2013). To the other side of the neglected brain: the hyperexcitability of the left intact hemisphere. *Neuroscientist* 19, 208–217. doi: 10.1177/1073858412447874
- Lhermitte, J., and Tchehrazi, E. (1937). L'image du moi corporel et ses déformations pathologiques. *Encéphale* 32, 1–24.
- Manfredini, A., Mancini, F., Posteraro, L., and Savazzi, S. (2013). The two sides of spatial representation in neglect patients: the same spatial distortion for different patterns of performance. *Neuropsychologia* 51, 1867–1877. doi: 10.1016/j.neuropsychologia.2013.06.013
- Milner, A. D., and Harvey, M. (1995). Distortion of size perception in visuospatial neglect. *Curr. Biol.* 5, 85–89.
- Milner, A. D., Harvey, M., and Pritchard, C. L. (1998). Visual size processing in spatial neglect. *Exp. Brain Res.* 123, 192–200.
- Paqueron, X., Leguen, M., Rosenthal, D., Coriat, P., Willer, J. C., and Danziger, N. (2003). The phenomenology of body image distortions induced by regional anaesthesia. *Brain* 126, 702–712.
- Paulhan, J. (1993). *Braque ou la Peinture Sacrée*. Paris: L'Échoppe, 1–19.
- Podoll, K., and Robinson, D. (2002). Splitting of the body image as somesthetic aura symptom in migraine. *Cephalalgia* 22, 62–65.
- Ricci, R., Calhoun, J., and Chatterjee, A. (2000). Orientation bias in unilateral neglect: representational contributions. *Cortex* 36, 671–677.
- Ricci, R., Pia, L., and Gindri, P. (2004). Effects of illusory spatial anisometry in unilateral neglect. *Exp. Brain Res.* 154, 226–237.
- Rode, G., Michel, C., Rossetti, Y., Boisson, D., and Vallar, G. (2006). Left size distortion (hyperschematia) after right brain damage. *Neurology* 67, 1801–1808.



- Rode, G., Pagliari, C., Huchon, L., Rossetti, Y., and Pisella, L. (2017). Semiology of neglect: an update. *Ann. Phys. Rehabil. Med.* 60, 177–185. doi: 10.1016/j.rehab.2016.03.003
- Rode, G., Revol, P., Rossetti, Y., and Vallar, G. (2008). 3D left hyperschemata after right brain damage. *Neurocase* 14, 369–377. doi: 10.1080/13554790802389154
- Rode, G., Ronchi, R., Revol, P., Rossetti, Y., Jacquin-Courtois, S., Rossi, I., et al. (2014). Hyperschemata after right brain damage: a meaningful entity? *Front. Hum. Neurosci.* 8:8. doi: 10.3389/fnhum.2014.00008
- Rode, G., Vallar, G., Revol, P., Tilikete, C., Jacquin-Courtois, S., Rossetti, Y., et al. (2012). Facial macrosomatognosia and pain in a case of Wallenberg's syndrome: selective effects of vestibular and transcutaneous stimulations. *Neuropsychologia* 50, 245–253.
- Ronchi, R., Bolognini, N., Gallucci, M., Chiappella, L., Algeri, L., Spada, M. S., et al. (2014). (Un)awareness of unilateral spatial neglect: a quantitative evaluation of performance in visuo-spatial tasks. *Cortex* 61, 167–182. doi: 10.1016/j.cortex.2014.10.004
- Ronchi, R., Posteraro, L., Fortis, P., Bricolo, E., and Vallar, G. (2009). Perseveration in left spatial neglect; drawing and cancellation tasks. *Cortex* 45, 300–312. doi: 10.1016/j.cortex.2008.03.012
- Rusconi, M. L., Maravita, A., Bottini, G., and Vallar, G. (2002). Is the intact side really intact? Perseverative responses in patients with unilateral neglect: a productive manifestation. *Neuropsychologia* 40, 594–604.
- Saj, A., Catalano Chiuvi, S., Brugger, C., van der Meulen, M., and Assal, F. (2011). Ipsilateral hyperschemata without spatial neglect after right frontal lesion. *J. Neurol. Sci.* 308, 142–143. doi: 10.1016/j.jns.2011.06.040
- Savazzi, S., Posteraro, L., Veronesi, G., and Mancini, F. (2007). Rightward and leftward bisection biases in spatial neglect. two sides of the same coin? *Brain* 130, 2070–2084.
- Struiksma, M. E., Noordzij, M. L., and Postma, A. (2009). What is the link between language and spatial images? Behavioral and neural findings in blind and sighted individuals. *Spat. Work. Mem. Imagery* 132, 145–156. doi: 10.1016/j.actpsy.2009.04.002
- Vallar, G. (1998). Spatial hemineglect in humans. *Trends Cogn. Sci.* 2, 87–97.
- Vallar, G., and Bolognini, N. (2014). “Unilateral spatial neglect,” in *Oxford Handbook of Attention*, eds A. C. Nobre and S. Kastner (Oxford: Oxford University Press), 972–1027.
- Vallar, G., and Papagno, C. (2003). “Pierre Bonnier's (1905) cases of bodily ‘aschématie,’” in *Classic Cases in Neuropsychology*, Vol. 2, eds C. Code, C.-W. Wallesch, Y. Joannette, and A. R. Lecours (Hove: Psychology Press), 147–170.
- Vallar, G., and Rode, G. (2009). Commentary on Bonnier P. L'aschématie. *Rev. Neurol.* 16, 397–400.
- Vallier, D. (1954). Braque, la peinture et nous. Propos de l'artiste recueillis par Dora Vallier. *Cahiers d'art N 2*, 70–82.
- Zaidel, D. W. (2013). Split-brain, the right hemisphere, and art: fact and fiction. *Prog. Brain Res.* 204, 3–17. doi: 10.1016/B978-0-444-63287-6.00001-4

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# Verbal Creativity Is Correlated With the Dynamic Reconfiguration of Brain Networks in the Resting State

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Creativity is the foundation of human culture. All inventions and innovations in history rely upon us to break with the traditional thinking and create something novel. A number of neuroimaging studies have explored the neural mechanism of creativity. However, a majority of researches have focused only on the stationary functional connectivity in resting-state fMRI and task-related fMRI, neglecting the dynamic variation of brain networks. Here, we used dynamic network analysis to investigate the relation between the dynamic reorganization of brain networks and verbal creativity in 370 healthy subjects. We found that the integration of the left lingual gyrus and left middle temporal gyrus (MTG) in default mode network (DMN) and the integration of the DMN and cerebellum, frontoparietal task control network (FPTC) and auditory network (Aud) showed positive correlation with verbal creativity performance. In addition, the recruitment of the bilateral postcentral gyrus from the sensory/somatomotor network (SMN) and the recruitment of the SMN in general displayed a significant correlation with verbal creativity scores. Taken together, these results suggested that the dynamic reorganization among the brain networks involved multiple cognitive processes, such as memory retrieval, imaginative process, cognitive control – these are all important for verbal creativity. These findings provided direct evidence that verbal creativity was related to the dynamic variation of brain mechanism during resting-state, extending past research on the neural mechanism of creativity. Meanwhile, these results brought about new perspectives for verbal creative training and rehabilitation training of depression.

**Keywords:** creativity, resting state, dynamic reorganization, brain networks, neural mechanism

## INTRODUCTION

Creativity is the foundation of human culture. All inventions and innovations in history rely upon us to break with the traditional thinking and create something novel. Creativity is generally defined as the capability of generating original and useful products (Runco and Jaeger, 2012). Based on the definition, the psychometric measurements about creative performance mostly depend on divergent thinking (DT) tasks, in which individuals are asked to think of several possible solutions to open questions (Runco and Acar, 2012). The most common DT task is the Alternative Uses Task (AUT), in which subjects should generate various suitable and creative usages of familiar items, such as a tin (e.g., “eating”) (Guilford, 1967). Then the answers are scored for three dimensions including

fluency (the amount of possible solutions), flexibility (the amount of solutions classifications), and originality (the unusual of solutions) (Guilford, 1967).

Recently, neural mechanism has increasingly been the hot topic of research in creativity. Although there is a lack of agreement about the neural mechanism of creativity, there was some overlap in brain activated regions, involving the prefrontal cortex (PFC) (Arden et al., 2010), middle temporal gyrus (MTG) (Mark et al., 2004; plosbiology, 2004), posterior cingulate cortex (PCC) (Dietrich and Kanso, 2010; Zhang H. et al., 2014), and posterior parietal cortex (PPC) (Howard-Jones et al., 2005; Mashal et al., 2007). A meta-analysis based on the activation likelihood estimation showed that the lateral PFC, PPC, and left MTG were typically activated under DT tasks (Xin et al., 2015). Furthermore, Wei et al. (2014) reported that the great DT tasks performance was related to stronger strength of functional connectivity (FC) between the medial PFC and the MTG during resting-state. Meanwhile, some studies showed the results of brain structure in creativity. For example, better creativity performance was related to increased gray matter thickness in the right PCC (Clark et al., 2013). Lower gray matter thickness in the lingual gyrus was correlated to higher DT tasks scores (Mula et al., 2016).

However, the process of generating novel ideas is not only involved in some specific brain regions. Rather, it mostly depended on cooperation among multiple brain networks (Dietrich, 2007; Dietrich and Kanso, 2010). Recently, research has also focused on the large-scale functional networks in creativity, and revealed two key networks: default mode network (DMN) and frontoparietal network (FPN). The DMN comprised of the medial PFC, the PCC, the precuneus, the MTL, and bilateral inferior parietal lobes (IPL), which were often activated in DT tasks (Fink et al., 2010; Sun et al., 2013). This network was consistently activated in the absence of external task demands and deactivated during an external task (Kim et al., 2014; Luo et al., 2015). As it was in the absence of cognitive control (van den Heuvel and Hulshoff Pol, 2010), the DMN may be a benefit to the creative thoughts to enter our consciousness (van den Heuvel and Hulshoff Pol, 2010; Beaty et al., 2014). The FPN was associated with the top-down control of cognitive and executive. It included lateral prefrontal and anterior inferior parietal regions, which were also continually activated in creativity tasks (Abraham et al., 2012; Zabelina and Andrews-Hanna, 2016). Regions of the FPN played a critical roles in the process of generating novel ideas. For example, great cognitive manipulation facilitated the concentration of thoughts details and the assessment of the usefulness of creative ideas (Carter and Veen, 2007; Ellamil et al., 2012).

In addition, a great deal of recently published papers have revealed the relationship between FC of the DMN and FPN and creative performance (Beaty et al., 2014; Shi et al., 2018b). For example, Zhu et al. (2017) showed that the coupling between the DMN and FPN was obviously associated with creativity scores. However, a majority of research has focused only on the stationary functional connectivity in resting-state fMRI and task-related fMRI. The latest studies have revealed that brain network organizations varied more and less at any time (Zhang

X. et al., 2014), which makes it possible to study the fluctuation characteristics of the brain networks over time by following the immediate interaction patterns among brain regions (Madhyastha et al., 2015; Tagliazucchi and Laufs, 2015). To date, most studies about the association between the brain networks and creativity overlooked the dynamic reorganization of the brain networks. Intriguingly, the flexibility among the networks has been proved to be associated with cognitive flexibility (Bassett et al., 2011; Bertolero et al., 2015). Dietrich (2004) showed that creativity was the essence of cognition flexibility, which could promote change of thinking to adapt environmental variation, and bring about the production of creative ideas and invention (Dietrich, 2004; Barbey et al., 2013). All in all, the cognition flexibility in creative people may reflect in dynamic changeability and reorganization among the brain networks during the resting state. Therefore, the present study investigated the correlation between the dynamic reorganization of brain networks and creativity. In the current study, the participants completed an AUT and intelligence test after measured neuroimaging. Given that the past studies had indicated that creative thinking was related to the cooperation between the DMN and FPN (Beaty et al., 2014, 2015; Zhu et al., 2017; Shi et al., 2018b), we hypothesized that the dynamic communication between the DMN and FPN might be also related to creative performance. To address this hypothesis, we used dynamic network construction and multilayer community detection to explore the relationship between dynamic communication patterns among the brain networks and creative performance.

## MATERIALS AND METHODS

### Participants

A total of 410 healthy undergraduates were recruited from Southwest University in China. Seventeen participants did not complete the behavioral test, and fifteen participants did not participate in the scanning. Eight subjects were excluded because the maximal head motion between volumes in each direction exceeded 3 mm or rotation about each axis exceeded 3°. Then, 370 undergraduates (166 males; mean age = 19.98,  $SD = 1.27$ ) were included in the next analyses. Based on a self-report questionnaire before scanning, none of them had reported a history of neurological or mental illness or substance abuse. All subjects signed the written informed consents. This study was approved by the Institutional Review Board of Southwest University Imaging Center.

### Assessment of Creativity

We measured creative cognition using AUT from the verbal form of the Torrance Tests of Creative Thinking (Torrance, 1974). Subjects were asked to list as many interesting and unusual uses as possible for a cardboard box using paper and pencil within 10 min. We calculated three different creative dimensions scores, including (1) originality (the ability to produce uncommon ideas), (2) flexibility (the ability to generate more different kinds of ideas), and (3) fluency (the ability to generate more meaningful ideas). Three trained raters assessed responses of all participants

based on previous guidance (Chen et al., 2014), and the inter-rater correlation coefficient was adequate (ICC > 0.90).

## Assessment of General Intelligence

As a test of general intelligence, all participants completed the Combined Raven's Test (CRT). The CRT consists of Raven's colored progressive matrix (A, B, and AB sets) and Raven's standard progressive matrix (C, D, and E sets), which have been widely used in Chinese populations with a high degree of reliability and validity in measuring general intelligence (Wang et al., 2007; Tang et al., 2012). The index of general intelligence was calculated by the total number of correct answers given in 40 min.

## Data Acquisition and Preprocessing

Functional imaging data were collected on a Siemens 3T Trio scanner (Siemens Medical Systems, Erlangen, Germany). Resting-state fMRI was conducted with the following EPI sequences: TR = 2000 ms, TE = 30 ms, field of view (FOV) = 220 × 220, flip angle = 90°, slices = 32, thickness = 3 mm, slice gap = 1 mm, voxel size = 3.4 × 3.4 × 4 mm<sup>3</sup>. The scanning lasted 8 min and contained 242 volumes. During the scanning, all participants were asked to close eyes and rest, but not to fall asleep.

The fMRI data were preprocessed using the advanced Data Processing Assistant for Resting-State fMRI (DPARSF<sup>1</sup>) (Chao-Gan and Yu-Feng, 2010; Yan et al., 2016), which is based on Statistical Parametric Mapping (SPM<sup>2</sup>). Specifically, the first 10 time points were discarded to suppress the equilibration effects and accommodate subjects' adaptation to the environment. The remaining volumes were slice timing corrected, realigned, and spatially normalized to the MNI template and resampled to 3 × 3 × 3 mm<sup>3</sup>. Then, nuisance signals including cerebrospinal fluid, white matter, and head motion parameters and their derivatives based on the Friston 24-parameter model were regressed out in order to control the potential influence of physiological artifacts (Friston et al., 2015). In order to better remove head motion effects, each bad time point was regarded as a regressor. The bad time points were defined as volumes with framewise displacement (FD, Jenkinson) > 0.2 mm, as well as the two volumes succeeding and one volume preceding any such. The Jenkinson FD (Jenkinson et al., 2002) was used due to its consideration of voxel-wise differences in motion in its derivation (Yan et al., 2013). Additionally, linear and quadratic trends were also included as regressors, since the BOLD signal exhibits low-frequency drift. Finally, we conducted spatial smoothing with 4 mm full width at half maximum Gaussian kernel and bandpass temporal filtering (0.01–0.1 Hz).

## Dynamic Network Construction

Large-scale networks were established according to Power's template, 264 regions are widely distributed across the whole brain and include fourteen large-scale networks (Power et al., 2011). Considering that signal intensity may be poorer in certain

locations of the brain, 11 nodes in locations of lower BOLD signal were identified and discarded by using Wig's approach (Wig et al., 2014); thus, 253 nodes were reserved. A sliding-window method was used to investigate the dynamic fluctuation of FC in each window. A time series of each ROI was acquired by averaging the BOLD signals from all voxels in this region, and the FC strength was examined by calculating the Pearson correlation of the time series between pairs of regions. Small and large windows were associated with a narrow range of network flexibility values across the brain, while medium windows (75 s, 100 s) uncovered a wide range of network flexibility (Telesford et al., 2016). Meanwhile, given that one TR is 2 s in this study and more windows are needed to track dynamic trajectories, window length was therefore set to 50 TRs, and the time gap of each window was set to 1TR, yielding 183 overlapping time windows to capture the temporal fluctuations of FC during a short period; next, Fisher's z-transformation was applied to improve normality.

## Multilayer Community Detection

To explore the temporal evolution of modular structure in dynamic FC, we used a generalized Louvain algorithm to find the putative functional modules that based on the optimization of the modularity quality function (Telesford et al., 2016). Considering the fact that the multiple adjacency matrices correspond to the consecutive single time window, we connected the adjacent time windows by adding interlayer connections between each node and itself in the adjacent window (Mucha et al., 2010; Bassett et al., 2011). More details about this algorithm was provided in the **Supplementary Material**.

## Recruitment and Integration

Results of the multilayer community detection are shown in a partition matrix (nodes × layers), whose elements represent the community assignment of brain region *i* in layer *l*. The multilayer modularity quality function simultaneously and optimized assigns brain regions to communities in all layers so that community labels are consistent across layers, thus avoiding the community matching problem (Mucha et al., 2010; Bassett et al., 2011). According to the optimal community partition, module allegiance provides a summary of the consistency with which ROIs are assigned to communities (Bassett et al., 2015; Chai et al., 2016). To measure the dynamic role of each region within and between networks, we used the module allegiance matrix to compute two coefficients: the dynamic network integration and the dynamic network recruitment (Bassett et al., 2015; Mattar et al., 2015). Recruitment was defined as the probability of a region assigned to the same community with other regions from the same network, while integration was defined as the probability of a region being assigned to the same community as regions in other networks (**Supplementary Material**).

## Correlation Analyses and Independent t-Test

To identify how the brain network dynamics may be related to individual creative cognition, we calculated the Pearson correlation between recruitment and integration (including the

<sup>1</sup><http://www.rfmri.org/DPARSF>

<sup>2</sup><http://www.fil.ion.ucl.ac.uk/spm>

region, network, and whole-brain levels) and the AUT score across all individuals, with gender, age, Raven's score, and mean FD being regressed out as covariates. The results surviving FDR ( $p < 0.05$ ) correction are reported. In addition, we calculated independent  $t$ -test to explore gender differences in creativity and intelligence scores.

## RESULTS

### AUT Performance

**Table 1** shows demographic information and Pearson correlation regarding all measures. There is no close correlation between Raven's score and AUT performance (originality,  $r = 0.07$ ,  $p = 0.18$ ; flexibility,  $r = 0.06$ ,  $p = 0.24$ ; fluency,  $r = 0.08$ ,  $p = 0.13$ ; total score,  $r = 0.08$ ,  $p = 0.15$ ). We also found a significant gender difference: an independent  $t$ -test indicated that females showed a higher AUT score than males (originality,  $t = 2.68$ ,  $p < 0.01$ ; flexibility,  $t = 2.02$ ,  $p < 0.05$ ; fluency,  $t = 2.30$ ,  $p < 0.05$ ; total score,  $t = 2.49$ ,  $p < 0.05$ ), although there was no difference in Raven's score ( $t = 1.16$ ,  $p = 0.25$ ). AUT and Raven's score were both compliance with normal distribution.

### Correlation of Recruitment With AUT Performance

After controlling for age, gender, Raven's score, and mean FD, the recruitment of several nodes showed a positive close correlation with AUT performance among the 253 nodes. Interestingly, most of these nodes were located in the sensory/somatomotor network (SMN). Specifically, the recruitment of three nodes from the SMN and one node from the visual network showed positive correlation with originality score; the recruitment of three nodes from the SMN displayed positive correlation with both fluency and total scores. However, the recruitment of one node from the DMN showed a negative correlation with originality and fluency scores, as shown in **Table 2**. Meanwhile, at the network level, we also found that the recruitment of the SMN displayed significant correlations with originality, fluency, and total scores (originality,  $r = 0.215$ ,  $p < 0.0001$ ; fluency,  $r = 0.191$ ,  $p < 0.001$ ; total score,  $r = 0.197$ ,  $p < 0.001$ ; FDR corrected), as shown in **Figure 1**.

### Correlation of Integration With AUT Performance

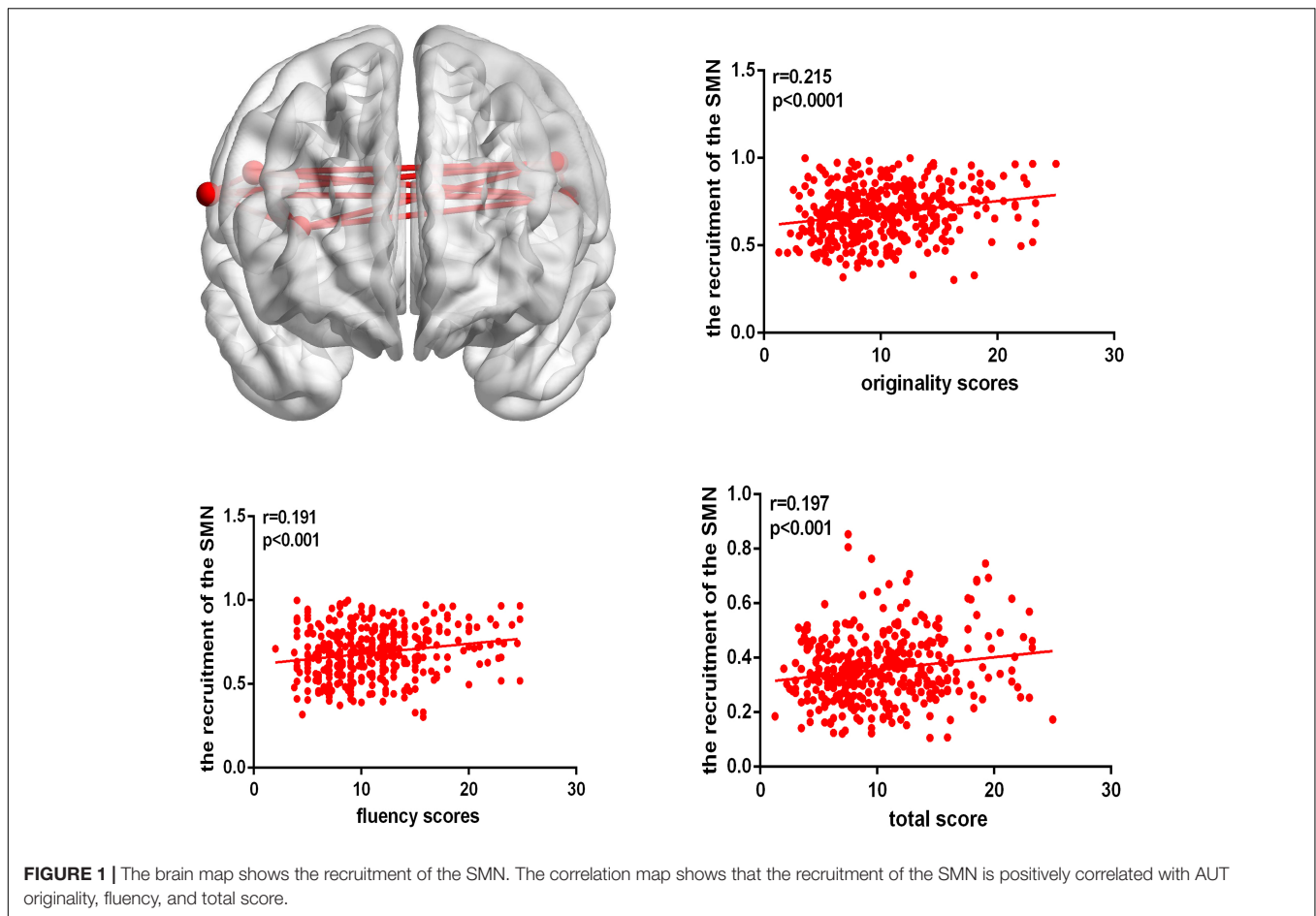
After controlling gender, age, Raven's score, and mean FD, the integration of two nodes (node number defined in the

**TABLE 1** | Demographic information and Pearson correlation.

Measures	Mean(SD)	Age	Raven	Originality	Flexibility	Fluency	AUT total score
Gender (166 males)							
Age	19.98(1.27)	–					
Raven	66.04(3.50)	–0.026	–				
Originality	10.30(4.64)	–0.080	0.070	–			
Flexibility	7.60(2.54)	–0.011	0.062	0.820**	–		
Fluency	11.06(4.68)	–0.045	0.079	0.922**	0.879**	–	
AUT total score	28.96(11.42)	–0.053	0.075	0.968**	0.917**	0.981**	–

**TABLE 2** | The recruitment and integration of nodes correlated with AUT score (FDR corrected).

	Node index	Anatomical automatic labeling	$r$	$p$
Originality (recruitment)	44	Postcentral_R (SMN)	0.200	$1.11 \times 10^{-4}$
	45	Postcentral_L (SMN)	0.227	$1.07 \times 10^{-5}$
	46	Postcentral_R (SMN)	0.196	$1.46 \times 10^{-4}$
	117	Temporal_Mid_L (DMN)	–0.174	$8.10 \times 10^{-4}$
	160	Lingual_L (Visual network)	0.186	$3.21 \times 10^{-4}$
Fluency (recruitment)	42	Postcentral_L (SMN)	0.197	$1.44 \times 10^{-4}$
	44	Postcentral_R (SMN)	0.191	$2.24 \times 10^{-4}$
	45	Postcentral_L (SMN)	0.210	$4.98 \times 10^{-5}$
	117	Temporal_Mid_L (DMN)	–0.178	$5.87 \times 10^{-4}$
Total score (recruitment)	42	Postcentral_L (SMN)	0.201	$9.77 \times 10^{-5}$
	44	Postcentral_R (SMN)	0.195	$1.63 \times 10^{-4}$
	45	Postcentral_L (SMN)	0.216	$2.91 \times 10^{-5}$
Originality (integration)	79	Lingual_L (DMN)	0.202	$9.53 \times 10^{-5}$
	117	Temporal_Mid_L (DMN)	0.186	$3.22 \times 10^{-4}$



Power template: 79 and 117) from the DMN showed a positive close correlation with originality scores (node 79,  $r = 0.202, p < 0.0001$ ; node 117,  $r = 0.186, p < 0.0005$ ; FDR corrected), as shown in **Table 2**. We also calculated the integration between pairs of networks, originality score showed a positive correlation with the integration of the DMN and cerebellum ( $r = 0.173, p < 0.001$ ), the ventral attention network (VAN) and SMN ( $r = 0.175, p < 0.001$ ), the salience network (SN) and auditory network

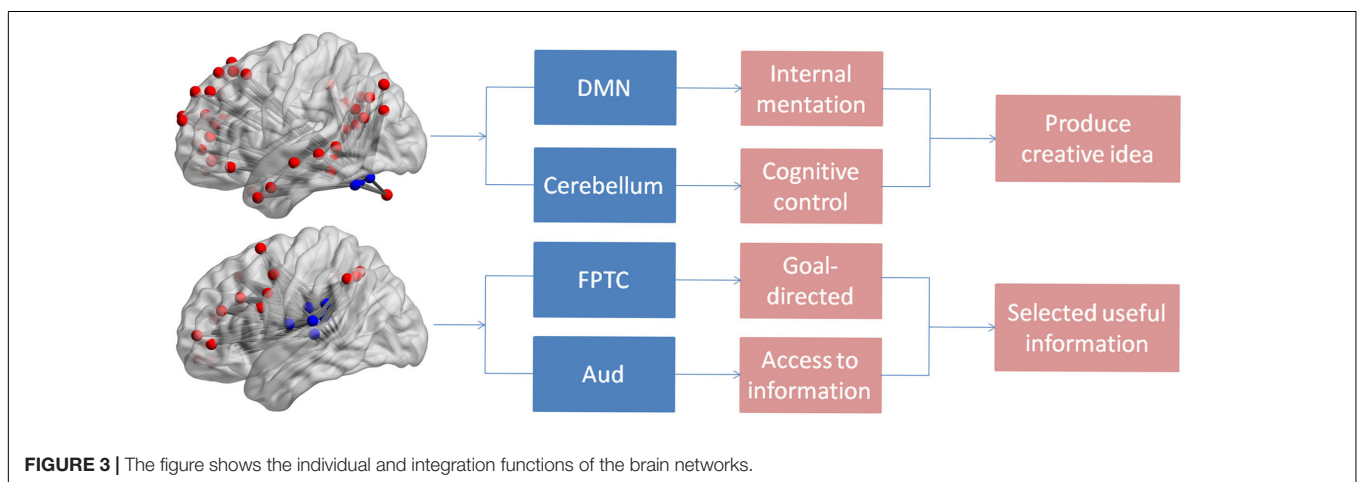
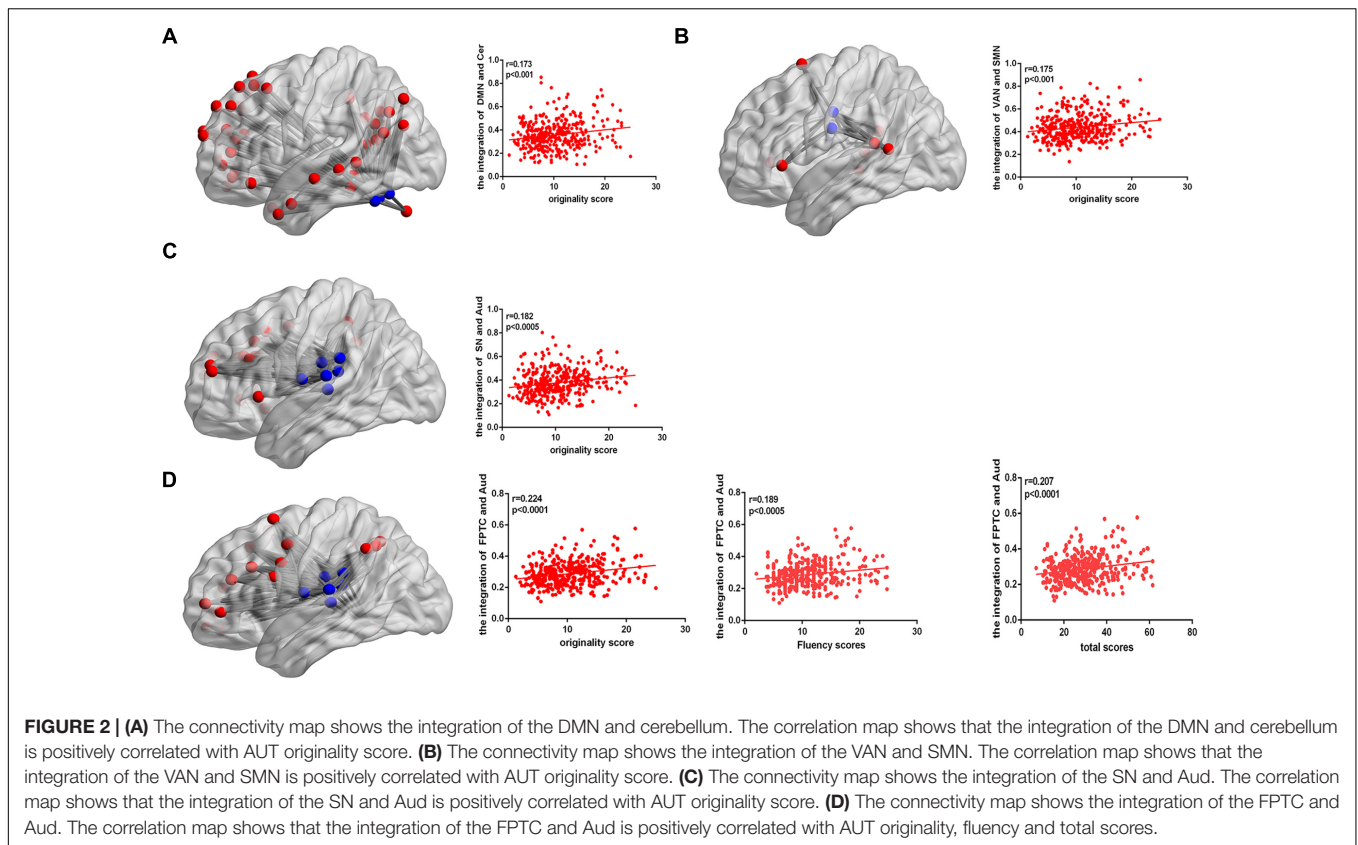
(Aud) ( $r = 0.182, p < 0.0005$ ), and the frontoparietal task control (FPTC) network and Aud ( $r = 0.224, p < 0.0001$ ), corrected by FDR. Fluency and total scores both displayed positive correlations with the integration of the FPTC and Aud (fluency,  $r = 0.189, p < 0.0005$ ; total scores,  $r = 0.207, p < 0.0001$ ; FDR corrected); flexibility score was also related to the integration of the FPTC and Aud ( $r = 0.174, p < 0.001$ , uncorrected), as shown in **Table 3** and **Figure 2**.

**TABLE 3 |** The integration between pairs of networks correlated with AUT score (FDR corrected).

AUT score	Pairs of network	r	p
Originality	DMN-Cer	0.173	$8.56 \times 10^{-4}$
	VAN-SMN	0.175	$9.75 \times 10^{-4}$
	SN-Aud	0.182	$4.43 \times 10^{-4}$
	FPTC-Aud	0.224	$1.02 \times 10^{-5}$
Fluency	FPTC-Aud	0.189	$2.50 \times 10^{-4}$
Total score	FPTC-Aud	0.207	$5.85 \times 10^{-5}$

## DISCUSSION

As far as we know, this is the first investigation exploring whether the dynamic reorganization of networks is correlated with verbal creativity using dynamic multilayer community detection approaches. We associated the dynamic of resting-state functional brain networks at three different levels (the regional level, the network level, and the whole-brain level) with the AUT performance to reveal the brain mechanisms of creativity. We found that the recruitment of bilateral postcentral gyrus in SMN showed a positive close correlation with AUT performance. Meanwhile, at the network level, we also found that the recruitment of the SMN displayed a significant correlation



with originality, fluency, and total scores. For integration, the left lingual gyrus and left MTG in the DMN showed a positive close correlation with originality scores. Furthermore, we revealed that 4 between-network integrations were clearly related to the AUT performance. Specifically, the integration of DMN and cerebellum, FPTC and Aud were involved. These results suggested that the dynamic communication among the brain networks concerning spontaneous thought, cognitive control, and external information inputs was significant for generating creative ideas. Meanwhile, previous research indicated the dynamic communication among the networks has been

association with cognitive flexibility (Dietrich, 2004), and our results further demonstrated the relationship between verbal creativity and cognition flexibility.

In the present study, we found individuals with greater creativity performance displayed stronger integration in DMN network including the left lingual and left MTG. The result might suggest individuals should retrieval previous memory during the process of creativity tasks. The medial temporal lobe memory network may facilitate generation of creative ideas by establishing association between old and new information (Ellamil et al., 2012). Previous studies showed that the lingual gyrus was

favorably activated in novel processes (Jung et al., 2010). At the network level, we found that verbal creativity performance was positively correlated to the integration of DMN and cerebellum. It is well known that DMN activity was mainly linked to internal mentation, such as mind wandering (Ionta et al., 2014) and future imagination (Stawarczyk and D'Argembeau, 2015). Thus activation of the DMN was involved in the process of generating creative ideas. Existing studies exposed that the cerebellum was relevant to cognitive control including visual attention and working memory (Brissenden et al., 2015). Meanwhile, Pidgeon et al. (2016) reported the cerebellum was also linked with the production of creativity improvisation and greater creative imagining in pictures (Pidgeon et al., 2016). The result of the integration of two networks being closely related to creativity showed the cooperation between spontaneous thought and cognitive control. It was contributed to generating more creative ideas that were consistent with current problems, as shown in **Figure 3**. Besides, increased functional connectivity between default network hubs and regions involved cognitive control was related to openness (Adelstein et al., 2011), and openness can strongly predicts performance on creative thinking tasks (Silvia et al., 2008), which could indirectly demonstrate the stronger correlation of DMN and cerebellum linked up with greater performance in verbal creative tasks. In addition, we also found that integration of FPTC and Aud were positively correlated with verbal creative performance, showing that the dynamic connectivity between the FPTC and Aud was associated with verbal creativity. The activity of the FPTC was related to many high-control cognitive functions which required an externally goal-directed process (Anselm et al., 2013). The integration of FPTC and Aud indicated that the stronger association of the goal-directed and auditory networks might facilitated selection of surrounding information from ears, as shown in **Figure 3**.

Regarding recruitment, we found that the recruitment of several nodes showed a positive close correlation with AUT performance among the 253 nodes; interestingly, most of these nodes were located in the SMN. Specifically, the recruitment of 3 nodes from the SMN, including the bilateral postcentral gyrus, showed a positive correlation with originality, fluency and total scores. These regions might benefit to emulating usage methods of items in somatosensory areas, which could be profitable for generating novel answers in AUT (Cousijn et al., 2014). In addition, at the network level, we found that the recruitment of the SMN displayed significant correlation with originality, fluency, and total scores. It could be concluded that high creative performance might require the SMN to remain stable at resting states, communicating mainly with other regions within the same network, lack of association with other network (Shi et al., 2018a). The results also explained why FC of the SMN and other brain networks has rarely been found in previous studies.

Prior research about verbal creativity have been interested in the gross network characteristics (Beatty et al., 2014) or static functional connections (Gao et al., 2017), thereby ignoring the dynamic reorganization of the brain networks. Here, we used dynamic neuroscience methods to track changes in the recruitment and integration of networks during resting states, and identified the correlation between the

dynamic reorganization of brain networks and verbal creativity. Furthermore, we found that creativity was related to multiple cognitive processes, including memory retrieval, imaginative process, and cognitive control, which suggested that it is possible to improve creative performance by training these basic cognitive processes. For example, if memory was improved, you would be able to more quickly extract previous memory and establish links between old memory and new information. In the same vein, if the ability of cognitive control was trained, you would accurately suppress unrelated information and mind. These process are important for generating novel ideas (Arden et al., 2010). Meanwhile, prior studies revealed significantly reduced FC between the cerebellum and the DMN in depression (Liu et al., 2012). On the contrary, we found verbal creativity performance was positively correlated to the integration of DMN and cerebellum, which provides the possibility of increasing functional connectivity between the cerebellum and the DMN through creativity trains to treat depressed patients.

This study also had some possible limitations. First, we used dynamic community detection algorithm to integrate brain regions into a coherent activation community. However, due to the inherent challenges of heuristic algorithms and fMRI data, node allocation at the individual subject level is still a statistical process with certain degree of uncertainty (Braun et al., 2015). Second, task-based fMRI is more meaningful for studying the dynamic variation of brain mechanism than resting-state fMRI. In the future, it would be necessary to research the dynamic variation of networks during creativity tasks. Finally, we used a single test (AUT) to represent a multidimensional conception (creativity), which was also insufficient. Future researches would employ multidimensional approaches of measuring creativity to find the comprehensive brain mechanism during creativity tasks.

## CONCLUSION

In summary, this is the first investigation to study the relationship between the dynamic reorganization of brain networks and verbal creativity using dynamic community detection. Our study found that the integration of left lingual and left MTG in DMN regions and the integration of DMN and cerebellum, FPTC and Aud showed positive correlation with verbal creativity performance. In addition, the recruitment of bilateral postcentral gyrus from the SMN and the recruitment of the SMN showed positive correlation with verbal creative performance. These findings provided direct evidence that verbal creativity was related to the dynamic variation of neural mechanism during resting-state, extending past research on the neural mechanism of verbal creativity. At the same time, this result brought about new perspectives for creative training and rehabilitation training of depression.

## ETHICS STATEMENT

This study was approved by the Institutional Review Board of Southwest University Imaging Center for Brain Research, all



participants signed the written informed consents and received payment for their participation.

## AUTHOR CONTRIBUTIONS

JQ and WY were responsible for design the experiments. QF was responsible for writing the article. LH and XW was responsible for analyzing the data. YZ was responsible for collecting the data.

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## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fpsyg.2019.00894/full#supplementary-material>

## REFERENCES

- Abraham, A., Beudt, S., Ott, D. V., and Yves von Cramon, D. (2012). Creative cognition and the brain: dissociations between frontal, parietal-temporal and basal ganglia groups. *Brain Res.* 1482, 55–70. doi: 10.1016/j.brainres.2012.09.007
- Adelstein, J. S., Shehzad, Z., Mennes, M., DeYoung, C. G., Zuo, X.-N., Kelly, C., et al. (2011). Personality is reflected in the brain's intrinsic functional architecture. *PLoS One* 6:e27633. doi: 10.1371/journal.pone.0027633
- Anselm, D., Christian, S., Andrei, M., Andreas, W., Meng, C., Hans, F., et al. (2013). Shifted intrinsic connectivity of central executive and salience network in borderline personality disorder. *Front. Hum. Neurosci.* 7:727. doi: 10.3389/fnhum.2013.00727
- Arden, R., Chavez, R. S., Grazioplene, R., and Jung, R. E. (2010). Neuroimaging creativity: a psychometric view. *Behav. Brain Res.* 214, 143–156. doi: 10.1016/j.bbr.2010.05.015
- Barbey, A. K., Colom, R., and Grafman, J. (2013). Architecture of cognitive flexibility revealed by lesion mapping. *Neuroimage* 82, 547–554. doi: 10.1016/j.neuroimage.2013.05.087
- Bassett, D. S., Wymbs, N. F., Porter, M. A., Mucha, P. J., Carlson, J. M., and Grafton, S. T. (2011). Dynamic reconfiguration of human brain networks during learning. *Proc. Natl. Acad. Sci. U.S.A.* 108, 7641–7646. doi: 10.1073/pnas.1018985108
- Bassett, D. S., Yang, M., Wymbs, N. F., and Grafton, S. T. (2015). Learning-induced autonomy of sensorimotor systems. *Nat. Neurosci.* 18:744. doi: 10.1038/nn.3993
- Beaty, R. E., Benedek, M., Kaufman, S. B., and Silvia, P. J. (2015). Default and executive network coupling supports creative idea production. *Sci. Rep.* 5:10964. doi: 10.1038/srep10964
- Beaty, R. E., Benedek, M., Wilkins, R. W., Jauk, E., Fink, A., Silvia, P. J., et al. (2014). Creativity and the default network: a functional connectivity analysis of the creative brain at rest. *Neuropsychologia* 64, 92–98. doi: 10.1016/j.neuropsychologia.2014.09.019
- Bertolero, M. A., Yeo, B. T., and D'Esposito, M. (2015). The modular and integrative functional architecture of the human brain. *Proc. Natl. Acad. Sci. U.S.A.* 112, E6798–E6807. doi: 10.1073/pnas.1510619112
- Braun, U., Schäfer, A., Walter, H., Erk, S., Romanczukseiferth, N., Haddad, L., et al. (2015). Dynamic reconfiguration of frontal brain networks during executive cognition in humans. *Proc. Natl. Acad. Sci. U.S.A.* 112, 11678–11683. doi: 10.1073/pnas.1422487112
- Brissenden, J., Levin, E., Osher, D., Rosen, M., Halko, M., and Somers, D. (2015). Cerebellar contributions to visual attention and visual working memory revealed by functional MRI and intrinsic functional connectivity. *J. Vis.* 15:232. doi: 10.1167/15.12.232
- Carter, C. S., and Veen, V. V. (2007). Anterior cingulate cortex and conflict detection: an update of theory and data. *Cogn. Affect. Behav. Neurosci.* 7, 367–379. doi: 10.3758/cabn.7.4.367
- Chai, L. R., Mattar, M. G., Blank, I. A., Fedorenko, E., and Bassett, D. S. (2016). Functional network dynamics of the language system. *Cereb. Cortex* 26, 4148–4159. doi: 10.1093/cercor/bhw238
- Chao-Gan, Y., and Yu-Feng, Z. (2010). DPARSF: a MATLAB toolbox for “pipeline” data analysis of resting-state fMRI. *Front. Syst. Neurosci.* 4:13. doi: 10.3389/fnsys.2010.00013
- Chen, Q., Yang, W., Li, W., Wei, D., Li, H., Lei, Q., et al. (2014). Association of creative achievement with cognitive flexibility by a combined voxel-based morphometry and resting-state functional connectivity study. *Neuroimage* 102, 474–483. doi: 10.1016/j.neuroimage.2014.08.008
- Clark, C. A. C., Fang, H., Espy, K. A., Filipek, P. A., Juranek, J., and Bangert, B. (2013). Relation of neural structure to persistently low academic achievement: a longitudinal study of children with differing birth weights. *Neuropsychology* 27, 364–377. doi: 10.1037/a0032273
- Cousijn, J., Zanolie, K., Munsters, R. J., Kleibeuker, S. W., and Crone, E. A. (2014). The relation between resting state connectivity and creativity in adolescents before and after training. *PLoS One* 9:e105780. doi: 10.1371/journal.pone.0105780
- Dietrich, A. (2004). The cognitive neuroscience of creativity. *Psychon. Bull. Rev.* 11, 1011–1026.
- Dietrich, A. (2007). *Introduction to Consciousness*. London: Macmillan.
- Dietrich, A., and Kanso, R. (2010). A review of EEG, ERP, and neuroimaging studies of creativity and insight. *Psychol. Bull.* 136, 822–848. doi: 10.1037/a0019749
- Ellamil, M., Dobson, C., Beeman, M., and Christoff, K. (2012). Evaluative and generative modes of thought during the creative process. *Neuroimage* 59, 1783–1794. doi: 10.1016/j.neuroimage.2011.08.008
- Fink, A., Grabner, R. H., Benedek, M., Reishofer, G., Hauswirth, V., Fally, M., et al. (2010). The creative brain: investigation of brain activity during creative problem solving by means of EEG and FMRI. *Hum. Brain Mapp.* 30, 734–748. doi: 10.1002/hbm.20538
- Friston, K. J., Williams, S., Howard, R., Frackowiak, R. S., and Turner, R. (2015). Movement-related effects in fMRI time-series. *Magn. Reson. Med.* 35, 346–355. doi: 10.1002/mrm.1910350312
- Gao, Z., Zhang, D., Liang, A., Liang, B., Wang, Z., Cai, Y., et al. (2017). Exploring the associations between intrinsic brain connectivity and creative ability using functional connectivity strength and connectome analysis. *Brain Connect.* 7, 590–601. doi: 10.1089/brain.2017.0510
- Guilford, J. P. (1967). *The Nature of Human Intelligence*. New York, NY: McGraw-Hill 249.
- Howard-Jones, P. A., Blakemore, S. J., Samuel, E. A., Summers, I. R., and Claxton, G. (2005). Semantic divergence and creative story generation: an fMRI investigation. *Brain Res. Cogn. Brain Res.* 25, 240–250. doi: 10.1016/j.cogbrainres.2005.05.013
- Ionta, S., Martuzzi, R., Salomon, R., and Blanke, O. (2014). The brain network reflecting bodily self-consciousness: a functional connectivity study. *Soc. Cogn. Affect. Neurosci.* 9, 1904–1913. doi: 10.1093/scan/nst185

- Jenkinson, M., Bannister, P., Brady, M., and Smith, S. (2002). Improved optimization for the robust and accurate linear registration and motion correction of brain images. *Neuroimage* 17, 825–841. doi: 10.1016/s1053-8119(02)91132-8
- Jung, R. E., Segall, J. M., Jeremy, B. H., Flores, R. A., Smith, S. M., Chavez, R. S., et al. (2010). Neuroanatomy of creativity. *Hum. Brain Mapp.* 31, 398–409. doi: 10.1002/hbm.20874
- Kim, R., Hyder, F., and Blumenfeld, H. (2014). *Physiological Basis of BOLD fMRI Decreases*. New York, NY: Springer.
- Liu, L., Zeng, L. L., Li, Y., Ma, Q., Li, B., Shen, H., et al. (2012). Altered cerebellar functional connectivity with intrinsic connectivity networks in adults with major depressive disorder. *PLoS One* 7:e39516. doi: 10.1371/journal.pone.0039516
- Luo, C., Li, Q., Lai, Y., Xia, Y., Qin, Y., Liao, W., et al. (2015). Altered functional connectivity in default mode network in absence epilepsy: a resting-state fMRI study. *Hum. Brain Mapp.* 32, 438–449. doi: 10.1002/hbm.21034
- Madhyastha, T. M., Askren, M. K., Boord, P., and Grabowski, T. (2015). Dynamic connectivity at rest predicts attention task performance. *Brain Connect.* 5, 45–59. doi: 10.1089/brain.2014.0248
- Mark, J. B., Bowden, E. M., Jason, H., Frymiare, J. L., Stella, A. L., Richard, G., et al. (2004). Neural activity when people solve verbal problems with insight. *PLoS Biol.* 2:E97. doi: 10.1371/journal.pbio.0020097
- Mashal, N., Faust, M., Hendler, T., and Jungbeeman, M. (2007). An fMRI investigation of the neural correlates underlying the processing of novel metaphoric expressions. *Brain Lang.* 100, 115–126. doi: 10.1016/j.bandl.2005.10.005
- Mattar, M. G., Cole, M. W., Thompson-Schill, S. L., and Bassett, D. S. (2015). A functional cartography of cognitive systems. *PLoS Comput. Biol.* 11:e1004533. doi: 10.1371/journal.pcbi.1004533
- Mucha, P. J., Richardson, T., Macon, K., Porter, M. A., and Onnela, J. P. (2010). Community structure in time-dependent, multiscale, and multiplex networks. *Science* 328, 876–878. doi: 10.1126/science.1184819
- Mula, M., Hermann, B., and Trimble, M. R. (2016). Neuropsychiatry of creativity. *Epilepsy Behav.* 57(Pt B), 225–229. doi: 10.1016/j.yebeh.2015.12.050
- Pidgeon, L. M., Madeleine, G., Duffy, A. H., Laura, H., Chris, M. T., Tijana, V., et al. (2016). Functional neuroimaging of visual creativity: a systematic review and meta-analysis. *Brain Behav.* 6, 1–26.
- plosbiology (2004). Neural basis of solving problems with insight. *PLoS Biol.* 2:e111. doi: 10.1371/journal.pbio.0020111
- Power, J. D., Cohen, A. L., Nelson, S. M., Wig, G. S., Barnes, K. A., Church, J. A., et al. (2011). Functional network organization of the human brain. *Neuron* 72, 665–678.
- Runco, M. A., and Acar, S. (2012). Divergent Thinking as an indicator of creative potential. *Creat. Res. J.* 24, 66–75. doi: 10.1080/10400419.2012.652929
- Runco, M. A., and Jaeger, G. J. (2012). The standard definition of creativity. *Creat. Res. J.* 24, 92–96. doi: 10.1080/10400419.2012.650092
- Shi, J., Yao, Y., Zhan, C., Mao, Z., Yin, F., and Zhao, X. (2018a). The relationship between big five personality traits and psychotic experience in a large non-clinical youth sample: the mediating role of emotion regulation. *Front. psychiatry* 9:648. doi: 10.3389/fpsy.2018.00648
- Shi, L., Sun, J., Ren, Z., Chen, Q., Wei, D., Yang, W., et al. (2018b). Large-scale brain network connectivity underlying creativity in resting-state and task fMRI: cooperation between default network and frontal-parietal network. *Biol. Psychol.* 135, 102–111. doi: 10.1016/j.biopsycho.2018.03.005
- Silvia, P. J., Winterstein, B. P., Willse, J. T., Barona, C. M., Cram, J. T., Hess, K. I., et al. (2008). Assessing creativity with divergent thinking tasks: exploring the reliability and validity of new subjective scoring methods. *Psychol. Aesthet. Creat. Arts* 2, 68–85. doi: 10.1037/1931-3896.2.2.68
- Stawarczyk, D., and D'Argembeau, A. (2015). Neural correlates of personal goal processing during episodic future thinking and mind-wandering: an ALE meta-analysis. *Hum. Brain Mapp.* 36, 2928–2947. doi: 10.1002/hbm.22818
- Sun, H., Ying, C., Zhao, X., Wang, X., Jiang, Y., Ping, W., et al. (2013). Abnormal activity of default mode network in GERD patients. *BMC Neurosci.* 14:69. doi: 10.1186/1471-2202-14-69
- Tagliazucchi, E., and Laufs, H. (2015). multimodal imaging of dynamic functional connectivity. *Front. Neurol.* 6:10. doi: 10.3389/fneur.2015.00010
- Tang, C., Li, A., Huang, H., Cheng, X., Gao, Y., Chen, H., et al. (2012). Effects of lead pollution in SY River on children's intelligence. *Life Sci. J.* 9, 458–464.
- Telesford, Q. K., Lynall, M. E., Vettel, J., Miller, M. B., Grafton, S. T., and Bassett, D. S. (2016). Detection of functional brain network reconfiguration during task-driven cognitive states. *Neuroimage* 142, 198–210. doi: 10.1016/j.neuroimage.2016.05.078
- Torrance, E. P. (1974). *The Torrance Tests of Creative Thinking-TTCT Manual and Scoring Guide: Verbal Test A, Figural Test*. Lexington, KY: Ginn.
- van den Heuvel, M. P., and Hulshoff Pol, H. E. (2010). Exploring the brain network: a review on resting-state fMRI functional connectivity. *Eur. Neuropsychopharmacol.* 20, 519–534. doi: 10.1016/j.euroneuro.2010.03.008
- Wang, D., Di, M., and Qian, M. (2007). A report on the third revision of combined raven's test (CRT-C3) for children in China. *Chin. J. Clin. Psychol.* 2007, 559–561.
- Wei, D., Yang, J., Li, W., Wang, K., Zhang, Q., and Qiu, J. (2014). Increased resting functional connectivity of the medial prefrontal cortex in creativity by means of cognitive stimulation. *Cortex* 51, 92–102. doi: 10.1016/j.cortex.2013.09.004
- Wig, G. S., Laumann, T. O., and Petersen, S. E. (2014). An approach for parcellating human cortical areas using resting-state correlations. *Neuroimage* 93(Pt 2), 276–291. doi: 10.1016/j.neuroimage.2013.07.035
- Xin, W., Wenjing, Y., Dandan, T., Jiangzhou, S., Qunlin, C., Dongtao, W., et al. (2015). A meta-analysis of neuroimaging studies on divergent thinking using activation likelihood estimation. *Hum. Brain Mapp.* 36, 2703–2718. doi: 10.1002/hbm.22801
- Yan, C. G., Cheung, B., Kelly, C., Colcombe, S., Craddock, R. C., Martino, A. D., et al. (2013). A comprehensive assessment of regional variation in the impact of head micro-movements on functional connectomics. *Neuroimage* 76, 183–201. doi: 10.1016/j.neuroimage.2013.03.004
- Yan, C. G., Wang, X. D., Zuo, X. N., and Zang, Y. F. (2016). DPABI: data processing & analysis for (Resting-State) brain imaging. *Neuroinformatics* 14, 339–351. doi: 10.1007/s12021-016-9299-4
- Zabelina, D. L., and Andrews-Hanna, J. R. (2016). Dynamic network interactions supporting internally-oriented cognition. *Curr. Opin. Neurobiol.* 40, 86–93. doi: 10.1016/j.comb.2016.06.014
- Zhang, H., Liu, J., and Zhang, Q. (2014). Neural representations for the generation of inventive conceptions inspired by adaptive feature optimization of biological species. *Cortex* 50, 162–173. doi: 10.1016/j.cortex.2013.01.015
- Zhang, X., Li, X., Jin, C., Chen, H., Li, K., Zhu, D., et al. (2014). Identifying and characterizing resting state networks in temporally dynamic functional connectomes. *Brain Topogr.* 27, 747–765. doi: 10.1007/s10548-014-0357-7
- Zhu, W., Chen, Q., Xia, L., Beaty, R. E., Yang, W., Tian, F., et al. (2017). Common and distinct brain networks underlying verbal and visual creativity. *Hum. Brain Mapp.* 38, 2094–2111. doi: 10.1002/hbm.23507

**Conflict of Interest Statement:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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