JOURNAL OF
Creative Behavior
Publication of the Creative Education Foundation™

CHRISTA L. TAYLOR
ARASH E. ZAGHI

The Nuanced Relationship Between Creative Cognition and the Interaction Between Executive Functioning and Intelligence

ABSTRACT

The current study addresses gaps in our understanding of the relationship between creative cognition, intelligence (IQ), and executive functioning (EF). Undergraduate students completed an IQ test, verbal and figural divergent thinking (DT) tests, and a self-assessment of EF, across four study sessions. Participant data ($N = 199$) were analyzed using linear regression and PROCESS moderation models. Results demonstrated that EF interacts with IQ to predict figural and verbal DT in distinct ways, with different patterns emerging from different methods of scoring DT. Using traditional DT scoring, *Gf* (but not *Gc*) significantly moderated the relationship between EF and scores on both verbal and figural DT tasks. Low EF was associated with diminished DT scores for those with low *Gf* scores, unrelated for those with relatively higher *Gf*, and enhanced scores for those with the highest *Gf*. Using originality ratio scores, low EF was associated with diminished originality in verbal DT responses for those with low IQ (both *Gf* and *Gc*), unrelated for those with relatively higher IQ, and enhanced originality for those with the highest *Gc* (but not *Gf*) scores. Thus, there are several nuances in the way that EF interacts with IQ to predict DT.

Keywords: divergent thinking, creativity, executive functioning, intelligence.

Understanding the processes underlying creative cognition and how those processes relate to individual differences in creative potential and ability is essential for understanding creativity (i.e., novel and useful ideas or products; Runco & Jaeger, 2012) in every arena of life. Creative potential is most commonly assessed using divergent thinking tasks, which measure ones' ability to generate multiple creative solutions to a given problem (Guilford, 1967). Although divergent thinking is not synonymous with creativity, the ability to generate ideas represents a key aspect of creative cognition (Barbot et al., 2019; Jauk, Benedek, & Neubauer, 2014; Runco & Acar, 2012). Research examining how individual differences in executive functioning (EF) and intelligence (IQ) relate to creative cognition has grown in recent years (see Benedek & Jauk, 2019). However, there is little understanding regarding how IQ may moderate the relationship between EF and creativity.

For instance, studies examining how syndromes associated with impaired EF (e.g., Attention Deficit Hyperactivity Disorder; ADHD) relate to creativity and divergent thinking frequently discuss—but rarely assess—the role of IQ. EF refers to the mental processes that exert top-down control over thought and action (e.g., inhibition, working memory, and shifting), as well as the higher-order abilities (e.g., reasoning, problem-solving, and planning) that they engender (Diamond, 2013; Friedman & Miyake, 2017), which are reflected in daily life by self-regulated behaviors (Barkley, 2014). Several studies have shown that low EF may relate to greater creativity for those with relatively higher IQ (Carson, Peterson, & Higgins, 2003; Kéri, 2011). However, the results of these studies are limited in several ways (e.g., relating to only one type of EF assessed in the lab and general IQ scores). The purpose of this study is to address this knowledge gap by examining how the behavioral concomitants of EF interact with fluid and crystallized IQ to predict verbal and figural divergent thinking.

EXECUTIVE FUNCTIONS AND CREATIVITY

Creative ideation has historically been thought to result from non-conscious, associative processes resulting in novel combinations of existing concepts in semantic memory (Ward, Smith, Steven, & Vaid, 1997).

In this view, the more conceptually unrelated ideas are, the more creative their combination will be (Benedek, Könen, Könen, & Neubauer, 2012; Mednick, 1962). Thus, a broader, rather than a narrower, focus of attention (i.e., defocused attention) is likely to result in more novel combinations because it increases the number of concepts an individual can attend to simultaneously. This line of reasoning has been used to explain positive associations found between creativity and both state and trait variables associated with low attentional control, such as alcohol intoxication and ADHD (Abraham, Windmann, Siefen, Daum, & Güntürkün, 2006; Jarosz, Colflesh, & Wiley, 2012; Norlander, 1999; White & Shah, 2006, 2016).

On the other hand, a growing body of research supports the controlled-attention theory of creativity (Beaty, Silvia, Nusbaum, Jauk, & Benedek, 2014), which suggests that creativity requires controlled, effortful processes to search semantic memory and inhibit common ideas (e.g., Benedek, Jauk, Sommer, Arendasy, & Neubauer, 2014). Performance on EF tasks and tests of cognitive abilities, including components of IQ that rely on such processes,[1] have been shown to relate positively to divergent thinking ability and real-world creative achievement (Benedek, Franz, Franz, Heene, & Neubauer, 2012; Forthmann, Holling, Çelik, Storme, & Lubart, 2017, Forthmann et al. 2019; Nusbaum et al., 2014; Nusbaum & Silvia, 2011; Silvia, Beaty, & Nusbaum, 2013; Zabelina, O'Leary, Pornpattananangkul, Nusslock, & Beeman, 2015; Zabelina, Saporta, & Beeman, 2016, Zabelina, Friedman, & Andrews-Hanna, 2019). Additionally, controlled experimental studies have shown that impairing cognitive control diminishes creative performance on divergent thinking tasks (Camarda et al., 2018; Taylor, 2019). These findings, along with research demonstrating that associative and executive abilities jointly contribute to creativity (Beaty et al., 2014; Benedek et al., 2017; Kenett, Beaty, Silvia, Anaki, & Faust, 2016), suggest that creative cognition relies on both associative and executive processes.

However, research assessing daily EF (i.e., self-reports of behavior that reflect individual differences in EF ability) point to an association between poorer EF and creativity. Several studies using self-report assessments of ADHD symptoms in non-clinical samples (e.g., college students) have found that scores are positively related to self-reported creative achievement, behavior, and divergent thinking performance (Boot, Nevicka, & Baas, 2017; Taylor, Esmaili Zaghi, Kaufman, Reis, & Renzulli, 2020; Taylor, Zaghi, Kaufman, Reis, & Renzulli, 2020; Zabelina, Condon, & Beeman, 2014). For example, Boot et al. (2017) found that college students' scores on the ADHD DSM-IV rating scale for adults (Kooij et al., 2005) positively predicted self-reported creative behavior and achievement, as well as originality on a problem construction task asking participants to redefine an everyday problem. Because behavioral manifestations of ADHD are suggested to result from impaired EF (e.g., Barkley, 1997; Hervey, Epstein, & Curry, 2004; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005), these scales assess the behavioral concomitants of impaired EF (Biederman et al., 2007). Some have suggested that one's level of intelligence influences the relationship between EF and creativity, yet further empirical data are needed to support this idea.

INTELLIGENCE AND CREATIVITY

The relationship between creativity and intelligence (i.e., the mental abilities necessary to adapt to, shape, and select ones' environment; Sternberg, 1997) has been debated and conceptualized in various ways, and much of the evidence regarding the nature of the relationship has been inconsistent (see Plucker & Esping, 2015). Meta-analytic evidence suggests that the relationship between intelligence and creative achievement is relatively weak (i.e., $r = .17$, Kim, 2008). The threshold effect, which suggests that there is a relationship between creativity and intelligence only up to a certain level of intelligence, implies that intelligence is a necessary, but not sufficient condition for creativity. This threshold was traditionally thought to be an IQ of approximately 120 (e.g., Barron, 1969). However, more recent evidence suggests that the threshold varies according to a task's demands and may be non-existent for some indicators of creativity, such as self-reported creative achievement (Jauk, Benedek, Dunst, & Neubauer, 2013). Varying IQ thresholds or differences in analytic techniques (Karwowski et al., 2016) may explain why some studies have not found evidence for a threshold effect (e.g., Kim, 2005; Preckel, Holling, & Wiese, 2006). However, much of the earlier work examining the threshold theory, and used in Kim's meta-analysis, used general intelligence scores.

[1] Components of *Gf* (most notably *Glr*, the ability to store, consolidate, and retrieve information in long-term memory; Schneider & McGrew, 2012) have been used as indicators of executive abilities in creativity studies (e.g., Beaty et al., 2014). There is considerable overlap in the constructs of EF and IQ, and some suggest that higher order EFs, such as reasoning and problem-solving, are synonymous with *Gf* (Diamond, 2013). However, correlations between scores on various EF tasks and *Gf* are inconsistent, with some studies demonstrating strong correlations and others showing minimal relations (see Rey-Mermet et al., 2019). Thus, EF and IQ may be considered related, but distinct constructs (Benedek et al., 2014).

Modern intelligence theories and IQ tests developed based on these theories account for separate, but distinct factors of cognitive abilities.

Most modern IQ tests are based on the Cattell–Horn–Carroll (CHC) model of cognitive abilities (Kaufman, 2009; Keith & Reynolds, 2010). This model combines Cattell and Horn's extended *Gf-Gc* theory (Horn & Noll, 1997) and Carroll's (1993) three-stratum theory of cognitive abilities (McGrew, 2009). The CHC model is a hierarchical model of cognitive abilities across three stratums; primary abilities (at stratum I) consists of over 80 related, but distinct, narrow abilities (e.g., spatial orientation, judging rhythms, algebraic reasoning), which are subsumed under nine broad abilities (at stratum II; though see McGrew, 2005 for extended model), further subsumed under general IQ (at stratum III). Thus, the broad abilities of fluid IQ (*Gf*), defined as the ability to use controlled mental processes to solve novel problems, and crystallized IQ (*Gc*), defined as the knowledge that one acquires through education and experience,[2] represent two separable factors of general IQ (Schneider & McGrew, 2012). Indeed, the relationship between IQ and creativity differs based on which broad cognitive ability is assessed (e.g., Silvia, 2008).

The relationship between IQ and creativity tends to be more evident when examining broad cognitive abilities as opposed to general IQ (e.g., Silvia, 2008). Because creative ideas build on existing knowledge, it stands to reason that more retained concepts (i.e., greater *Gc*) would lead to greater creativity when controlling for other cognitive abilities (e.g., broad retrieval ability). Indeed, *Gc* has been found to relate to divergent thinking ability, particularly up to a moderate level of *Gc* (Cho, Nijenhuis, Vianen, Kim, & Lee, 2010). However, correlations between *Gc* and creativity tend to be weaker than for other broad cognitive abilities, including *Gf* (see Silvia, 2008). Two studies found that, although *Gc* positively predicted ones' ability to generate creative metaphors, effects were smaller than those for *Gf* and broad retrieval ability (*Glr*) when included in the same model (Beaty & Silvia, 2013; Silvia et al., 2013). Numerous studies have found strong associations between *Gf* and creativity on divergent thinking tasks (Benedek, Franz, et al., 2012; Gilhooly, Fioratou, Anthony, & Wynn, 2007; Nusbaum & Silvia, 2011).

RELATION OF CREATIVITY TO THE INTERACTION OF EXECUTIVE FUNCTIONING AND INTELLIGENCE

Several studies have examined how EF, IQ, and creativity relate to one another (Benedek, Franz, et al., 2012; Benedek et al., 2014; Krumm, Arán Filippetti, & Gutierrez, 2018; Pan & Yu, 2018). However, these studies have primarily examined how IQ and different components of EF, such as shifting (e.g., Pan & Yu, 2018), simultaneously predict creativity or how IQ mediates the relationship between EF and creativity. Fewer studies have examined how IQ may *interact* with EF to influence creativity (i.e., moderate the relationship). The studies that have examined how IQ moderates the relationship between EF and creativity have reported that diminished ability in one type of EF, latent inhibition (i.e., the ability to ignore irrelevant information in the environment), relates to greater creativity for those with relatively higher IQ (Carson et al., 2003; Kéri, 2011; though see Burch, Hemsley, Pavelis, & Corr, 2006).

Carson et al. (2003) found that college students who scored high (as opposed to low, using a median split) on self-reported creative achievement scored significantly lower on a latent inhibition task across two studies. Participants were exposed to random bursts of white noise while being asked to count the number of times they heard a nonsense syllable, after which they were asked to identify in as few trials as possible the auditory stimulus that preceded the appearance of disks on a video screen. Participants who took longer to identify that the burst of white noise preceded the disk than others who completed the first task without the bursts of white noise were suggested to have poorer latent inhibition. When participants from both studies were categorized into four groups (based on low versus high latent inhibition and IQ), participants with high IQ and low latent inhibition scored higher on the Creative Achievement Questionnaire (Carson, Peterson, & Higgins, 2005) than the other three groups (though the interaction was not significant). These results were later replicated by Kéri (2011), using a visual search task to assess latent inhibition and a community sample of adults with a more moderate mean IQ of 112 (as opposed to a mean IQ $\geq$ 125 in the Carson et al. studies). Carson et al. suggested that intelligence may allow individuals with diminished latent inhibition to be more creative because it allows them to work effectively with the unfiltered information. This research has been influential in work relating diminished EF to creativity, as well as to the development

[2] *Gc* has been referred to as crystallized intelligence, crystallized knowledge, and comprehension knowledge in different papers referenced. Likewise, *Gf* has been referred to as fluid intelligence and fluid reasoning. We use crystallized intelligence (or *Gc*) and fluid intelligence (or *Gf*) throughout the remainder of the paper when referencing these studies and our results for consistency.

of the shared vulnerability model (Carson, 2011, Carson 2014), which would suggest that low EF and high levels of IQ results in greater creativity (e.g., Kenett et al., 2016). However, several gaps in our understanding of how EF interacts with IQ to influence creativity remain.

THE PRESENT STUDY

Studies of the relation between syndromes associated with impairments in EF (e.g., ADHD) and creative cognition frequently discuss the potential moderating role of IQ. However, the few studies that have directly examined how IQ may moderate the relationship between EF and creativity have only assessed EF ability using performance on specific tasks (e.g., latent inhibition; Carson et al., 2003). These studies have advanced our understanding of some of the underlying processes, yet they have not accounted for the confluence of symptoms and characteristics that indicate poor EF in daily life. Additionally, previous studies have used general IQ scores, leaving the role of the related yet distinct broad abilities of *Gc* and *Gf* in this relationship unclear. Most importantly, although these results are explained in terms of the mechanisms underlying creative cognition, they are primarily relevant for creative achievement.

The purpose of the current study is to address these gaps in our understanding of the relationship between creative cognition, IQ, and the co-occurring dimensions of symptoms that result from poor EF. Thus, we examine how daily EF interact with *Gf* and *Gc* to predict verbal and figural divergent thinking. Given that previous studies assessing the behavioral concomitants of poor EF have found that they are positively related to creativity (Boot et al., 2017; Taylor, Esmaili Zaghi, et al., 2020; Zabelina et al., 2014), we expect to find a positive association between low EF and divergent thinking (*Hypothesis 1*). However, the relationship between one indicator of EF (i.e., latent inhibition) and divergent thinking has been shown to depend on IQ (Carson et al., 2003; Kéri, 2011) and it has been suggested that this may be the case for EF in general (e.g., Boot et al., 2017). Therefore, we expect that IQ will moderate the relationship between low EF and divergent thinking, such that the relationship will be stronger for individuals with relatively higher IQ (*Hypothesis 2*).

METHOD

This study was approved by the Institutional Review Board of the participating university (protocol #H17-196).

PARTICIPANTS

A total of 220 undergraduate students[3] were recruited from engineering programs at a public university in the Northeastern United States using flyers and emails sent to their student account. Data for participants who withdrew from the study (N = 20) or were not eligible for participation[4] (N = 1) were discarded. This resulted in a sample of 199 participants (56.3% men, 43.7% women), ranging in age from 18 to 33 years old (M = 19.89, SD = 1.86). Participants were compensated with a $35 gift card (prorated at $8.75 per session) after completing or withdrawing from the study.

MATERIALS

Barkley Deficits in Executive Functioning Scale (BDEFS)

The BDEFS (Barkley, 2011) is an 89-item self-report survey of behaviors that represent five dimensions of executive functioning deficits (i.e., time management, self-motivation, self-restraint, self-organization/problem-solving, and self-regulation of emotion). The items assess observable everyday behaviors, such as "*have trouble doing things in their proper order or sequence*" and "*likely to do things without considering the consequences for doing them.*" Participants indicate, on a scale from 1 (never) to 4 (very often), how often they have experienced each within the previous six months. A total scale score, reflecting poorer overall daily EF, is obtained by summing the scores across all subscales. The BDEFS exhibited strong internal consistency reliability (Cronbach's α = .96) in the current study.

The BDEFS was developed and validated using a nationally representative sample of adults in the U.S. (Barkley, 2011). Although the scale was originally developed to assess EF impairments associated with

[3] The number of participants recruited accommodated power considerations for a different study (in preparation), as it required a greater number of participants and uses some of the data collected for this study. However, for reference, a linear multiple regression with three predictors requires 162 participants for 90% power to detect a small to medium effect with α =.05 (according to G*Power 3.1; Faul, Erdfelder, Buchner, & Lang, 2009).

[4] One participant was revealed to be under 18 years old after completing the study.

ADHD, poor EF has also been found to negatively impact those without clinically significant disorders (e.g., Biederman et al., 2006). Recent studies have provided evidence that the scale can be used to assess non-clinical samples, using a Spanish-speaking community sample of college students and adults in Puerto Rico (Vélez-Pastrana et al., 2016) and a large sample of college students across five universities in the U.S. (Kamradt et al., 2019).

The Kaufman Brief Intelligence Test, Second Edition (KBIT-2)

The KBIT-2 (Kaufman & Kaufman, 2004) is a relatively brief test of intelligence, consisting of three subtests (verbal knowledge, matrices, and riddles), which demonstrates strong associations with full-scale IQ tests. The verbal knowledge subtest contains 60-items that ask participants to indicate which of six pictures on an easel corresponds to each word read by the administrator. The matrices subtest contains 46 items that ask participants to indicate either which of five pictures corresponds with a concept conveyed by a stimulus or which of six pictures completes a presented matrix. The riddles subtest contains 39 items that ask participants to respond with the correct word to a question read by the administrator. The number of items completed by each participant on the subtests is determined by a start point determined by age and a stop rule determined by incorrect responding. The verbal score is comprised of the scores for verbal knowledge and riddles subtests and reflects broad crystallized ability (*Gc*). The nonverbal score is comprised of the matrices subtest and reflects the broad abilities of fluid reasoning (*Gf*) and visual processing (*Gv*). Although an IQ composite indicating general intelligence may also be computed, the current study uses only the verbal and nonverbal IQ scores.

Torrance Tests of Creative Thinking (TTCT)

Divergent thinking was assessed using Form A of the TTCT-Verbal and Form A of the TTCT-Figural (Torrance, 2008). The tests were administered in accordance with the instruction manual. The TTCT-Verbal test contains five separate activities, ranging from 5 to 10 minutes, that require a written response (e.g., providing as many creative uses for a cardboard box as possible). Responses are scored for fluency (total number of responses), originality (infrequency of responses), and flexibility (variability in categories of responses). The TTCT-Figural test contains three separate drawing activities (e.g., providing as many creative pictures from a series of parallel lines as possible), each completed in 10 minutes. Responses are scored for fluency (total number of responses), originality (infrequency of responses), elaboration (detail of responses), resistance to premature closure (lack of constraint of responses), and titles (abstractness of the title provided for responses).

Traditional DT scoring

Scores obtained from three trained and certified raters at Scholastic Testing Services (STS) demonstrated strong inter-rater reliability on all subtests (Cronbach's $\alpha > .98$). Raters' scores were averaged to create total dimension scores for each participant. Dimension scores on the TTCT-Verbal test demonstrated strong internal consistency (Cronbach's $\alpha = .91$) and were strongly, positively correlated with one another ($r = .86$ to.98). Dimension scores on the TTCT-Figural test demonstrated acceptable internal consistency (Cronbach's $\alpha = .76$) and were also significantly, positively correlated with one another (albeit with several weaker correlations; $r = .18$ to.64). Total scores for the TTCT-Verbal and TTCT-Figural tests were created by averaging the scores (after z-transformation based on the sample) for each dimension on the corresponding tasks to account for differing rating scales.

This method of weighing the separate assessments equally and combining them using standard scores is the method used to provide the average standard score by STS. However, their standard scores are based on grade or age-based norms (Torrance, 2018). Because our TTCT forms did not contain personally identifying information for our participants, the average standard scores provided by STS for our sample are imprecise.

Originality ratio scores

Originality ratio scores, in which the originality score was divided by the fluency score for the corresponding task, were also calculated from the raw TTCT dimension scores provided by STS. Originality scores on divergent thinking tasks most closely align with conceptual definitions of creativity (e.g., Forthmann et al., 2017). However, traditional scoring methods do not account for the confounding effect of fluency on additive originality scores (i.e., the number of responses scored may artificially inflate to the originality score, regardless of the actual originality of each response; e.g., Forthmann, Szardenings, &

Holling, 2020; Silvia et al., 2008). Forthmann et al. (2020) recently provided convincing evidence that much of the overlap between additive originality and fluency is artifactual and suggested reporting ratio scores to examine originality controlling for fluency when relating the scores to creativity outcomes.

However, correlations between originality ratios (originality/fluency) and fluency were significant (at $p < .01$) for both verbal ($r = .42$) and figural ($r = -.21$) divergent thinking, suggesting that the relationships between originality and fluency on the TTCT tasks were not purely artifactual according to the guidelines suggested by Forthmann et al. (2020). To allow for comparison with previous studies using traditional scoring methods, we report originality ratios and traditional scores for the TTCT and discuss the differing results in the discussion.

PROCEDURE

Participants completed four separate study sessions in a private office on different days, lasting approximately 30–60 minutes each. During the first session, participants completed informed consent and the TTCT-Figural test. During the second session, participants used a tablet to complete the BDEFS on the Qualtrics platform. All scale items were presented in a random order, along with items from several other scales (e.g., personality survey and social support scale) for use in a different study (Taylor & Zaghi, 2021). During the third session, participants completed an engineering design activity, intended for use in a different study, followed by administration of the KBIT-2. During the fourth session, participants completed the TTCT-Verbal test. Additional participant information was collected after completion of the study that is not pertinent to these analyses (Taylor & Zaghi, 2021).

DATA ANALYSIS

Moderation models were tested using the PROCESS macro for SPSS (Hayes, 2018) to determine if EF interacts with IQ to predict divergent thinking scores and originality ratios. Significant moderators were examined using the Johnson-Neyman technique, which tests effects across the range of values of the moderator and provides regions of significance (i.e., values of the moderator at which an effect becomes statistically signficant; Bauer, Curran, & Thurstone, 2005). Additionally, effects were illustrated using the pick-a-point approach with values at the mean and $\pm$ 1 *SD* from the mean.

RESULTS

PRELIMINARY ANALYSES

Distributions for the variables did not deviate substantially from normal, with the exception of distributions for BDEFS scores and figural originality ratios. The BDEFS distribution did not deviate from normal after removing data for two outliers (> $\pm$ 3.5 SD from the mean). The distribution of figural originality ratios continued to be substantially positively skewed (skew = .85, $SE = .18$) after removing data for eight outliers. Therefore, regression models were examined both before and after square root transformation of the figural originality ratios, after which the distribution met the assumption of normality. Descriptive statistics and bivariate correlations among all variables may be seen in Table 1.

ANALYSES FOR DIVERGENT THINKING SCORES

Because moderation models in PROCESS do not provide estimates for the unconditional effect of X on Y, two linear regression tests were first conducted for verbal and figural divergent thinking individually. Results demonstrated that EF scores did not significantly predict scores on the TTCT-Verbal, $F(1, 195) = 2.76$, $p = .10$, or TTCT-Figural, $F(1, 195) = .11$, $p = .74$.

Gc (i.e., verbal IQ) did not significantly moderate the relationship between EF scores and verbal divergent thinking, $F(1, 192) = 1.63$, $p = .20$, $\Delta R^2 = .01$, or between EF scores and figural divergent thinking, $F(1, 192) = .02$, $p = .90$, $\Delta R^2 = .00$ (Table 2).

However, *Gf* (i.e., nonverbal IQ) significantly moderated the relationship between EF and verbal divergent thinking, $F(1, 192) = 10.56$, $p < .01$, $\Delta R^2 = .05$. As seen in Figure 1, the relationship between EF scores (with higher scores indicating poorer EF) and verbal divergent thinking was negative among those with relatively lower and mid-level *Gf*, yet positive among those with relatively higher *Gf*. According to the Johnson-Neyman technique (Figure 2), EF scores significantly predicted verbal divergent thinking ($p < .05$) for those with *Gf* scores less than 107.20 and greater than 130.27.

Gf also moderated the relationship between EF and figural divergent thinking, $F(1, 192) = 6.09$, $p < .05$, $\Delta R^2 = .03$. As seen in Figure 1, the relationship between EF scores (with higher scores indicating poorer EF)

TABLE 1. Descriptive Statistics and Pearson Correlations for Measured Variables

Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1. BDEFS	–						
2. KBIT-2 verbal (*Gc*)	−.02	–					
3. KBIT-2 nonverbal (*Gf*)	.08	.36**	–				
4. TTCT-Verbal	−.12	.26**	−.01	–			
5. TTCT-Figural	−.02	.14*	−.06	.44**	–		
6. Verbal originality ratio	−.08	.16*	.13	.48**	.15*	–	
7. Figural originality ratio	.10	.20**	.11	.09	.07	.18*	–
N	197	198	198	199	199	199	191
Mean	156	107.58	108.14	.00	−.00	.75	.73
SD	32.29	12.94	13.65	.97	.72	.07	.19
Min. – Max.	98–245	66–145	70–132	−2.25–2.92	−1.76–2.25	.54–0.93	0.37–1.34
Skewness	.57 (.17)	.00 (.17)	−.40 (.17)	.30 (.17)	.18 (.17)	−.27 (.17)	.85 (.18)
Kurtosis	−.15 (35)	.58 (.34)	−15 (.34)	.05 (.34)	−.00 (.34)	−.35 (.34)	.71 (.35)

Note. Correlations with figural ratio scores after square root transformation (not shown) showed minimal value changes and no changes in statistical significance; Standard error in parentheses; TTCT verbal and figural scores are averaged z-scores of corresponding subscales; BDEFS = Barkley Deficits in Executive Functioning Scale; KBIT-2 = The Kaufman Brief Intelligence Test, Second Edition; TTCT = Torrance Tests of Creative Thinking. ** $p < .01$, *$p < .05$.

TABLE 2. Coefficients for Moderation Models with Divergent Thinking Scores as Outcomes

Model	Coeff.	SE	*t*	*p*	95% CI
Verbal Divergent Thinking					
Constant	1.96	2.78	.71	.48	−3.52, 7.42
BDEFS (X)	−.03	.02	−1.46	.15	−.06, .01
Gc (W)	−.01	.03	−.52	.61	−.06, .04
BDEFS × *Gc* (XW)	.00	.00	1.28	.20	−.00, .00
	F (3, 192) = 5.94, $p < .01$, $R^2 = .09$				
	ΔF (1, 192) = 1.63, $p = .20$, $\Delta R^2 = .01$				
Verbal Divergent Thinking					
Constant	9.35	2.81	3.33	.00	3.81, 14.89
BDEFS (X)	−.06	.02	−3.43	.00	−.10, −.03
Gf (W)	−.08	.03	−3.14	.00	−.13, −.03
BDEFS × *Gf* (XW)	.00	.00	3.25	.00	.00, .00
	F (3, 192) = 4.49, $p < .05$, $R^2 = .07$				
	ΔF (1, 192) = 10.56, $p < .01$, $\Delta R^2 = .05$				
Figural Divergent Thinking					
Constant	−.49	2.14	−.23	.82	−4.71, 3.73
BDEFS (X)	−.00	.01	−.16	.87	−.03, .02
Gc (W)	.01	.02	.26	.79	−.03, .04
BDEFS × *Gc* (XW)	.00	.00	.13	.90	−.00, .00
	F (3, 192) = 1.27, $p = .29$, $R^2 = .02$				
	ΔF (1, 192) = .02, $p = .90$, $\Delta R^2 = .00$				
Figural Divergent Thinking					
Constant	5.54	2.12	2.61	.01	1.35, 9.73
BDEFS (X)	−.03	.01	−2.48	.01	−.06, −.01
Gf (W)	−.05	.02	−2.59	.01	−.09, −.01
BDEFS × *Gf* (XW)	.00	.00	2.47	.01	.00, .00
	F (3, 192) = 2.33, $p = .08$, $R^2 = .04$				
	ΔF (1, 192) = 6.09, $p < .05$, $\Delta R^2 = .03$				

Note. The estimated coefficients for X and W should not be interpreted as main effects, as each is conditioned on the level of the other predictor equal to zero (see Hayes, 2018).

and figural divergent thinking was negative among those with relatively lower *Gf* and positive among those with relatively higher *Gf*. According to the Johnson-Neyman technique, EF scores significantly predicted figural divergent thinking at $p < .05$ for those with *Gf* scores lower than 95.13 and greater than 129.21. Thus, among those with lower *Gf*, poorer EF were negatively associated with verbal and figural divergent thinking scores. However, among those with higher *Gf*, poorer EF were positively associated with verbal and figural divergent thinking scores.

ANALYSES FOR ORIGINALITY RATIO SCORES

Linear regression tests showed that EF scores did not significantly predict verbal originality ratios, $F(1, 195) = 1.36$, $p = .25$, or figural originality ratios for untransformed scores, $F(1, 187) = 2.05$, $p = .15$, or transformed scores, $F(1, 187) = 1.84$, $p = .18$.

The relationship between EF and figural originality ratios was not significantly moderated by *Gc*, $F(1, 184) = .69$, $p = .41$, $\Delta R^2 = .00$, nor by *Gf*, $F(1, 184) = 2.43$, $p = .12$, $\Delta R^2 = .01$ (Table 3).

However, the relationship between EF and verbal originality ratios was significantly moderated by *Gc*, $F(1, 192) = 6.44$, $p < .05$, $\Delta R^2 = .03$. As seen in Figure 3, the relationship between EF scores (with higher scores indicating poorer EF) and verbal originality ratios was negative among those with relatively lower and mid-level *Gc*, yet positive among those with relatively higher *Gc*. According to the Johnson-Neyman technique (Figure 4), EF significantly negatively predicted verbal originality ratios ($p < .05$) for those with *Gc* scores less than 102.58 and positively predicted verbal originality ratios for those with *Gc* scores greater than 142.42.

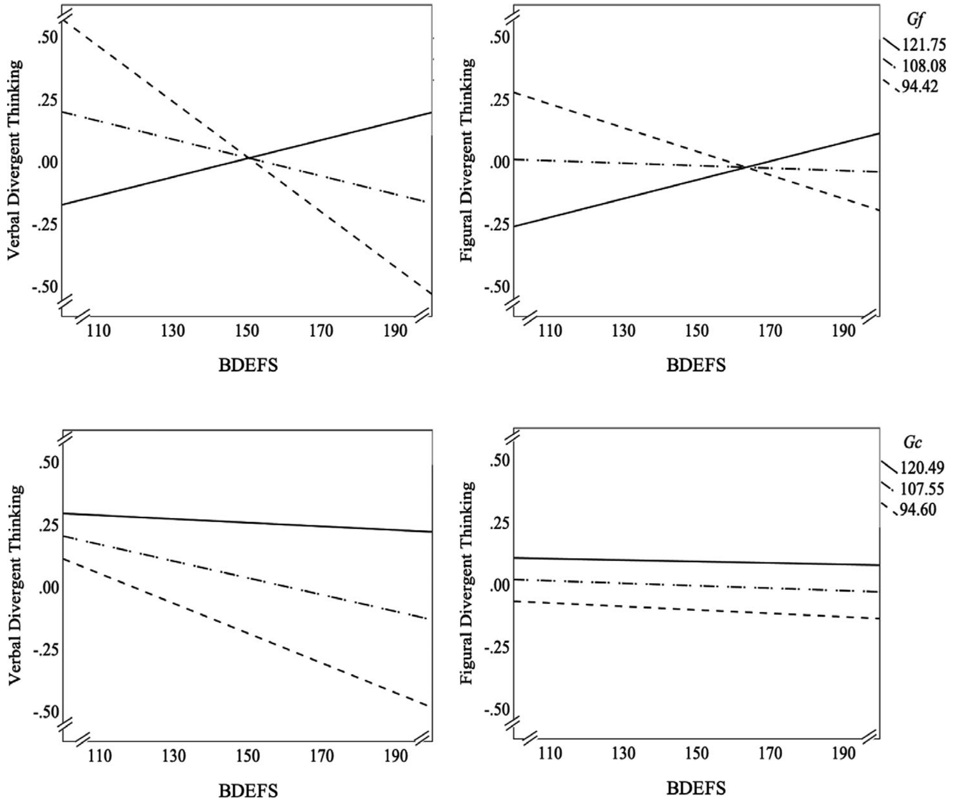

FIGURE 1. Visual representation of verbal and figural divergent thinking scores for those with Gf (top) and Gc (bottom) IQ scores at the Mean and ± 1 SD across BDEFS scores. *Note*. Figures are based on the pick-a-point approach, wherein line was fitted to means for each group at the Mean and ± 1 *SD* of BDEFS scores (for which higher scores reflect poorer EF).

The relationship between EF and verbal originality ratios was also significantly moderated by *Gf*, $F(1, 192) = 6.41$, $p < .05$, $\Delta R^2 = .03$. The relationship between EF scores (with higher scores indicating poorer EF) and verbal originality ratios was negative among those with relatively lower *Gf* and mid-level *Gf*, yet positive among those with relatively higher *Gf*. According to the Johnson-Neyman technique, EF significantly negatively predicted verbal originality ratios at $p < .05$ for those with *Gf* scores lower than 104.85.

Thus, among those with lower and mid-range IQs (both *Gc* and *Gf*), poorer EF was associated with lower verbal originality ratios. However, poorer EF was associated with higher verbal originality ratios among those with higher *Gc* (but not *Gf*) scores.

DISCUSSION

How diminished EF interacts with IQ to relate to creative cognition is frequently discussed (e.g., Boot et al., 2017; Taylor, Zaghi, et al., 2020), yet understudied. The few studies that have addressed this issue have assessed general IQ and self-reported creative achievement (Carson et al., 2003; Kéri, 2011), limiting our understanding of how the multiple dimensions of IQ may moderate this relationship, as well as how this relationship may function with creative cognition. We assessed daily EF along with distinct components of divergent thinking (figural and verbal) and IQ (*Gf* and *Gc*) to address these issues. Contrary to our first hypothesis, EF was not a significant predictor of verbal or figural divergent thinking, using traditional DT

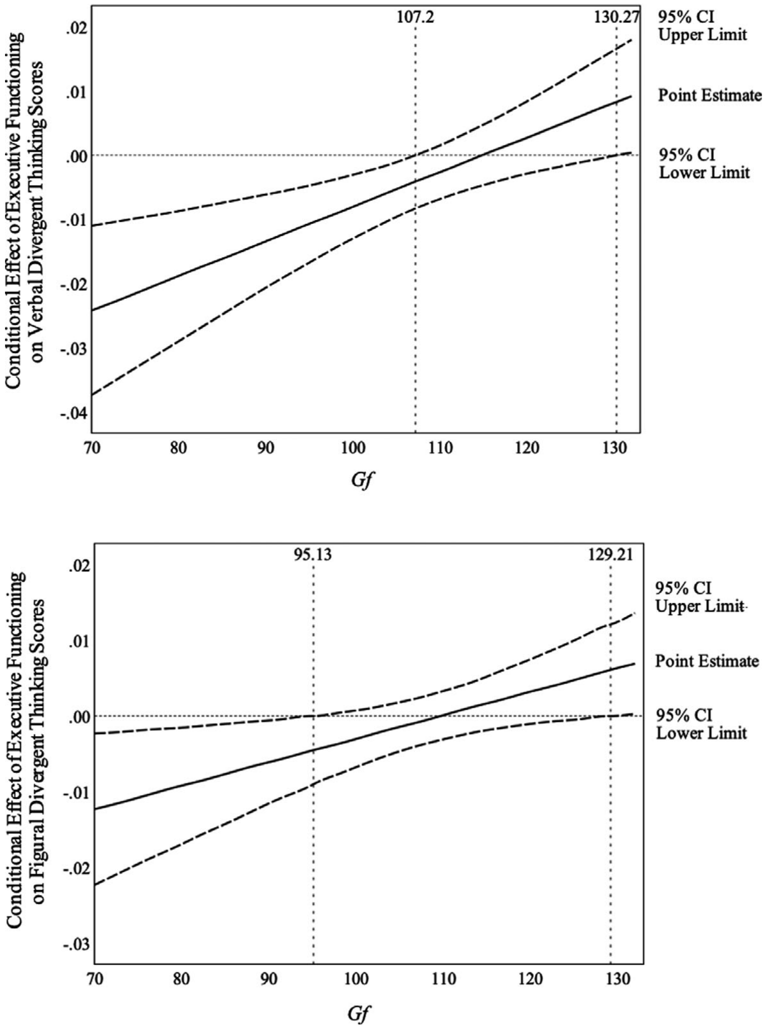

FIGURE 2. The conditional effect of executive functioning (with high scores indicating poorer EF) on verbal divergent thinking (top) and figural divergent thinking (bottom) as a function of Gf.

scoring or originality ratios.[5] Our second hypothesis was partially supported, though with different patterns according to the method used to score the DT tasks. Using traditional DT scoring, *Gc* (i.e., verbal IQ) did not significantly moderate the relationship between EF and either verbal or figural DT tasks. However, *Gf* (i.e., nonverbal IQ) was a significant moderator for both tasks. Poorer EF was associated with lower DT scores for those with relatively low levels of *Gf*, higher DT scores for those with relatively high levels of *Gf*, and was unrelated for those with *Gf* scores in between. Using originality ratio scores (originality score divided by the fluency score), the pattern of results did not differ by type of IQ, but rather by DT task. Neither *Gc* nor *Gf* significantly moderated the relationship between EF and figural originality ratios. However, both *Gc* and *Gf* were significant moderators for verbal originality ratios. In both cases, poorer EF was

[5] Although this differs from previous studies using non-clinical college samples (e.g., Boot et al., 2017; Taylor et al., 2020a), this result is not discussed in detail due to space limitations.

TABLE 3. Coefficients for Moderation Models with Originality Ratio Scores as Outcomes

Model	Coeff.	SE	*t*	*p*	95% CI
Verbal Originality Ratio					
Constant	1.19	.20	5.81	.00	.78, 1.59
BDEFS (X)	−.00	.00	−2.66	.01	−.01, −.00
Gc (W)	−.00	.00	−2.04	.04	−.01, −.00
BDEFS × *Gc* (XW)	.00	.00	2.53	.01	.00, .00
	F (3, 192) = 4.27, p < .05, R^2 = .06				
	ΔF (1, 192) = 6.44, p < .05, ΔR^2 = .03				
Verbal Originality Ratio					
Constant	1.21	.21	5.89	.00	.80, 1.61
BDEFS (X)	−.00	.00	−2.67	.01	−.01, −.00
Gf (W)	−.00	.00	−2.11	.04	−.01, −.00
BDEFS × *Gf* (XW)	.00	.00	2.53	.01	.00, .00
	F (3, 192) = 3.88, p < .05, R^2 = .06				
	ΔF (1, 192) = 6.41, p < 05, ΔR^2 = .03				
Figural Originality Ratio					
Constant	.74	.56	1.33	.19	−.36, 1.85
BDEFS (X)	−.00	.00	−.63	.53	−.01, .01
Gc (W)	−.00	.01	−.22	.83	−.01, .01
BDEFS × *Gc* (XW)	.00	.00	.83	.41	.00, .00
	F (3, 184) = 3.75, p < .05, R^2 = .06				
	ΔF (1, 184) = .69, p = .41, ΔR^2 = .00				
Figural Originality Ratio					
Constant	1.35	.57	2.36	.02	.22, 2.48
BDEFS (X)	−.01	.00	−1.40	.16	−.01, .00
Gf (W)	−.01	.01	−1.25	.21	−.02, .00
BDEFS × *Gf* (XW)	.00	.00	1.56	.12	.00, .00
	F (3, 184) = 2.19, p = .09, R^2 = .04				
	ΔF (1, 184) = 2.43, p = .12, ΔR^2 = .01				

Note. The estimated coefficients for X and W should not be interpreted as main effects, as each is conditioned on the level of the other predictor equal to zero (see Hayes, 2018).

associated with lower verbal originality ratios for those with relatively low levels of IQ and were unrelated for those with mid-to-high range IQs. Although poorer EF was associated with higher verbal originality ratios for those with the highest *Gc*, the lack of this effect for *Gf* may be due to more restricted *Gf* scores in the sample. Taken together, our results support the assertion that the relationship between EF and creativity depends on IQ and task type and reveal several possible nuances to this relationship.

Different patterns of results were found for moderation models using traditional DT scoring and originality ratios. Traditional DT scores, the average of equally weighted scores for different indicators of DT (e.g., originality, fluency, and flexibility), may be overly influenced by fluency (Forthmann et al., 2020; Silvia et al., 2008). Indeed, posthoc analyses for fluency scores alone mirrored the pattern of results obtained for the traditionally scored DT tasks. For traditionally scored DT tasks, IQ scores reflecting *Gf* (but not *Gc*) moderated the relationship between EF and both verbal and figural DT. Thus, an individual's acquired knowledge (i.e., *Gc*) may not significantly affect the relationship between their executive functioning and their ability to provide many responses on a DT task. However, their ability to work effectively with information (i.e., *Gf*) does significantly affect this relationship, providing a buffer against poor EF that may undermine ones' ability to provide many responses. Of note, the lower threshold at which EF no longer significantly predicted traditionally scored verbal and figural DT differed by more than 10 points in *Gf*. Thus, higher levels of *Gf* may be necessary to work effectively with verbal (compared to figural) information in the face of poor EF (see Jauk et al., 2013).

Models using originality ratios (originality divided by fluency) revealed a different pattern of results, wherein IQ moderated the relationship between EF and verbal (but not figural) originality ratios. Poor EF

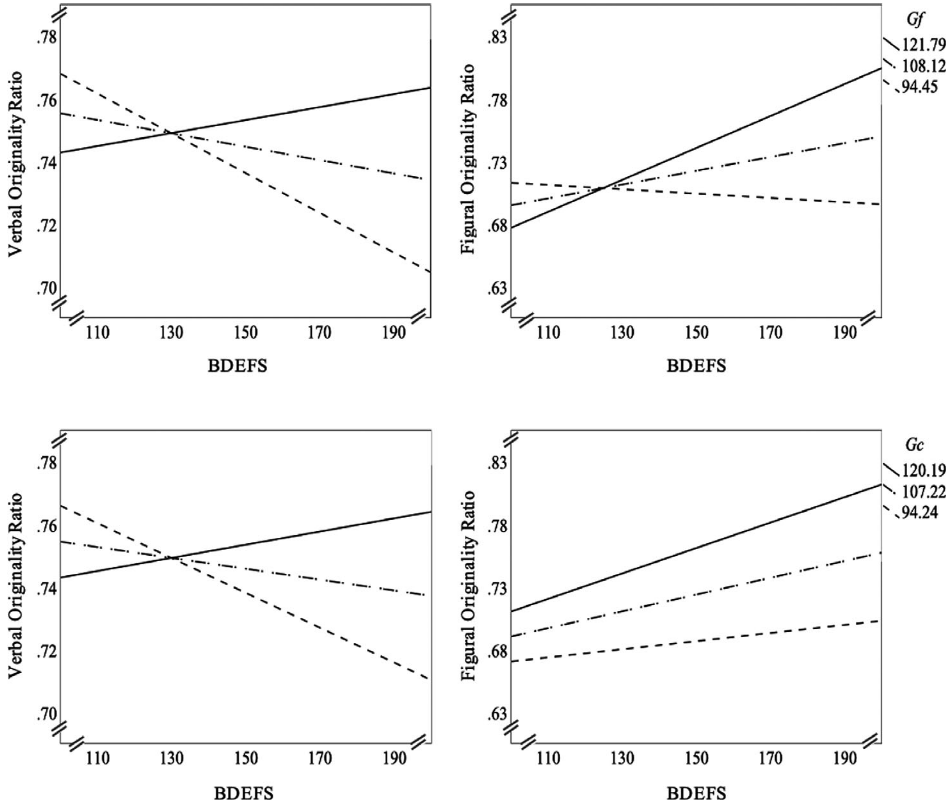

FIGURE 3. Visual representation of verbal and figural originality ratio scores for those with Gf (top) and Gc (bottom) IQ scores at the Mean and ± 1 *SD* across BDEFS scores. *Note*. Figures are based on the pick-a-point approach, wherein line was fitted to means for each group at the mean and ± 1 SD of BDEFS scores (for which higher scores reflect poorer EF).

was detrimental to the originality of verbal divergent thinking responses in those with relatively low IQ (both *Gf* and *Gc*). The lower threshold at which executive functioning no longer significantly predicted verbal creativity was similar for *Gf* and *Gc* (104.77 and 102.58, respectively). Poorer EF was also significantly associated with greater verbal creativity in those with high *Gc* (i.e., above 142.35). Although there was no upper threshold at which EF became associated with enhanced ability for *Gf*, it is possible that *Gf* would show a similar upper threshold with higher *Gf* scores, as the highest *Gf* score in the sample was 132. Because originality ratios control for the confounding effects of fluency, they may more accurately reflect the concept of creativity (see Forthmann et al., 2020). Thus, the creative processes that lead to more original verbal DT responses may be either unaffected or enhanced with poorer EF for those with higher IQ. These results are somewhat consistent with theory and research suggesting that diminished EF may be advantageous for creative cognition in certain circumstances (e.g., in those with high IQ; e.g., Carson, 2014). However, this was not the case for the originality of figural DT responses, revealing that the effect may differ by domain/task.

THEORETICAL IMPLICATIONS

Daily EF interacted with IQ to relate to divergent thinking in ways consistent and inconsistent with the shared vulnerability model (Carson, 2011, 2014). The basic tenet of the shared vulnerability model is that individuals with a genetic propensity for certain vulnerability factors (e.g., cognitive disinhibition and neural hyperconnectivity) may manifest either creativity or psychopathology, depending on the absence or presence

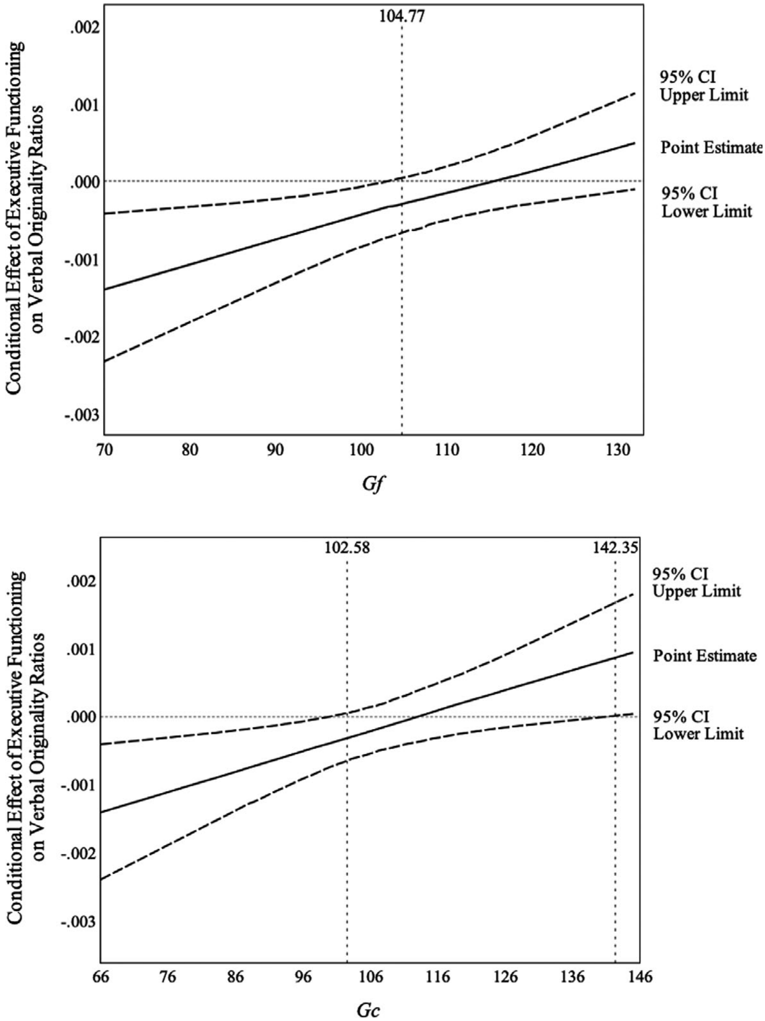

FIGURE 4. The conditional effect of executive functioning (with high scores indicating poorer EF) on verbal originality ratios as a function of Gf (top) and Gc (bottom).

of certain protective factors (e.g., requisite levels of IQ and cognitive flexibility). This has been suggested to mean that high levels of both vulnerability and protective factors will result in greater creativity (e.g., Kenett et al., 2016). Although evidence for this interaction has been presented for creative achievement, creative cognition has been suggested to be the underlying mechanism. Although we did indeed find higher verbal originality ratios for those with relatively higher IQ and poorer EF, this was not the case for figural originality ratios. Domain or task-based differences in divergent thinking indicates that the mechanisms underlying the interaction between IQ and EF may not relate to global differences in creative processing.

Differences in the methodology used in our study and the previous studies examining how IQ moderates the relationship between EF and creativity highlights several alternative possibilities. Our measure of EF captured problems with overall daily functioning compared with lab-tasks assessing targeted EF abilities, such as latent inhibition (e.g., Carson et al., 2003; Kéri, 2011). Self-assessments of daily EF behaviors and EF tasks are rarely related to one another (e.g., Kamradt, Ullsperger, & Nikolas, 2014; Toplak, West, & Stanovich, 2017). There may be global differences in creative processing that relate specifically to latent inhibition and IQ that were obscured in our study by using a self-report measure of EF. However, it may also be the case that the relationship functions differently for divergent thinking and creative achievement. Divergent thinking ability has been found to be related to flexible cognitive control (i.e., the ability to switch between focused and defocused attention), whereas artistic creative achievement is indeed related to latent inhibition (i.e., "leaky attention"; Zabelina, 2018; Zabelina et al., 2015, 2016). However, Zabelina et al. (2016) found that *scientific* creative achievement was not related to latent inhibition, again suggesting that the relationship may not apply to creativity globally.

LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

Although the current study fills important gaps in our understanding of how IQ and EF relate to creativity, there are several limitations to consider for future research. The current study is unique from other studies assessing problems with daily EF and creativity in non-clinical samples (Boot et al., 2017; Taylor, Zaghi, et al., 2020; Zabelina et al., 2014) in that both figural and verbal divergent thinking were assessed. However, the interaction between IQ and EF may relate differently to other indicators of creativity. Indicator-based differences may be inferred from previous studies demonstrating that latent disinhibition interacts with IQ to predict creative achievement (Carson et al., 2003; Kéri, 2011) and has distinct direct associations with different indicators of creativity (i.e., creative achievement vs. divergent thinking; Zabelina et al., 2015, 2016). Thus, our results are limited to divergent thinking, and future studies should include other assessments measuring creative potential and ability. Similarly, latent disinhibition has been found to relate to creativity in distinct ways for different domains on the same assessment (e.g., artistic vs. scientific creative achievement; Zabelina et al., 2016). Along with our results demonstrating differential functioning for verbal and figural divergent thinking, this suggests that future research should also include additional creative domains.

Our use of a self-report measure of EF was necessary to examine behaviorally defined problems in functioning, rather than more targeted executive functions. However, self-report scales are frequently criticized, in part because they are vulnerable to being influenced by several well-established biases (Fryer & Dinsmore, 2020; Paulhus & Vazire, 2005). Although self-report scales of EF have been shown to be valid indicators of impaired functioning (Biederman et al., 2007), an additional option in future studies would be to use reports of participants' behavior by those close to them, in addition to self-report. Indeed, the self-report scale used in the current study (i.e., the BDEFS) is also available in an informer-report format (Barkley, 2011). It is also worth noting that scores on EF tasks and self-rated scales of EF are rarely associated with one another (e.g., Kamradt et al., 2014; Toplak et al., 2017). EF tasks have their own set of criticisms, such as contamination by cognitive processes that are not considered EF (see Burgess et al., 2006) or by general cognitive ability (e.g., Biederman et al., 2008). Additionally, because tasks are used to assess narrow abilities of EF in lab settings, self-report measures may have better ecological validity (e.g., Barkley & Murphy, 2011). However, it would be interesting to include both EF tasks and self-assessments in future studies to examine if they interact with IQ in different ways to predict creativity.

CONCLUSION

The present study found that EF interacts with different components of IQ to predict figural and verbal divergent thinking in distinct ways, with different patterns also emerging from different methods of scoring DT. Results for traditional DT scores showed that EF interacts with different components of IQ to predict DT in distinct ways; Only *Gf* (as opposed to *Gc*) significantly moderated the relationship between EF and these scores on both verbal and figural DT tasks. In contrast, results using originality ratios, which mitigate the confounding effects of fluency in DT tasks and more closely align with conceptualizations of creativity (e.g., Forthmann et al., 2020), showed that EF interacts with IQ to predict different assessments of DT in distinct ways; *Gf* and *Gc* significantly moderated the relationship between EF and verbal, but not figural, originality ratios. Thus, this study highlights several nuances in the relationship between creativity, IQ, and executive functioning, providing multiple avenues for future research.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to disclose.

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Christa L. Taylor, Université catholique de Louvain

Arash E. Zaghi, University of Connecticut

Correspondence concerning this article should be addressed to Christa L. Taylor, Université catholique de Louvain, IPSY Place Cardinal Mercier 10/L3.05.01, 1348 Louvain-la-Neuve, Belgium. E-mail: christa.taylor@uclouvain.be

AUTHOR NOTE

This material is based upon work supported by the Division of Engineering Education and Centers of National Science Foundation (NSF) under Grant No. 1653854. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. The data that support the findings of this study are available on request from the PI (A.E.Z.). The data are not publicly available due to privacy or ethical restrictions. We would like to thank Connie Syharat for her significant contribution to data collection.