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Leveraging divergent thinking to enhance the academic performance of engineering students with executive functioning difficulties

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ABSTRACT

Executive functioning (EF) is a set of high-level cognitive skills, including planning, organizing, prioritizing, logical and contextual thinking, understanding, working memory, and self-monitoring. Though these skills are critical for academic success across fields, engineering education may be especially demanding for those with poor EF. One potential resource that may help to buffer against the negative effects of poor EF on academic achievement is divergent thinking. This study examined the role of divergent thinking as a moderating variable in the relationship between EF and academic achievement in engineering education. Undergraduate engineering students completed a self-report scale of EF and tests assessing figural and verbal divergent thinking, across multiple study sessions. Participants' GPA was obtained from the university registrar's office. Participant data ($N = 199$) were analyzed using correlational analysis and a multiple moderation model. Results showed that EF scores and engineering GPA were significantly negatively correlated, and that figural (yet not verbal) divergent thinking moderated the association. A greater frequency of behaviors reflecting problems with overall daily EF was associated with lower GPA for those with relatively lower figural divergent thinking ability. Thus, figural divergent thinking may be one personal resource that can be leveraged to enhance academic achievement in engineering students with poor EF.

1. Introduction

Executive functioning (EF), the ability to exert control over thought and action,[1] impacts one's daily functioning and quality of experience across important areas of life (Moffitt et al., 2011; Williams & Thayer, 2009). One context where poor EF may be particularly detrimental is in post-secondary education. College presents new challenges for students, independent of intellectual ability, as they simultaneously gain a greater level of autonomy and responsibility for their academic success (Perry, Hladkyj, Pelletier

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[1] The term executive functions refers to high-level cognitive skills including: 1) the mental processes that exert top-down control over thought and action (e.g., inhibition, working memory, and shifting), 2) the higher-order abilities that these processes engender (e.g., reasoning, problem-solving, and planning), 3) and the self-regulated behaviors occurring in daily life that stem from these processes and abilities (e.g., Barkley, 2014; Diamond, 2013; Friedman & Miyake, 2017). In the present research, we use executive functioning to refer to the everyday behavioral concomitants of these processes, rather than the narrow cognitive abilities frequently measured using in-lab tasks (see Diamond, 2013).

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& Pekrun, 2001, 2005). Indeed, previous research has shown that poor EF is associated with poorer academic achievement in the general student population (Biederman et al., 2006; Munro et al., 2017; Norwalk et al., 2009; Petersen et al., 2006). Post-secondary education in certain fields, such as engineering, differs from other academic areas in ways that may make it even more demanding for those with poor EF (Veenstra, Dey & Herrin, 2009). Thus, identifying personal resources that may be cultivated to help enhance both the academic performance and future career success of engineering students is of interest.

One such resource that has not yet been examined is divergent thinking, the ability to generate many original and diverse responses to a stimulus (Guilford, 1956, 1967). Divergent thinking and related abilities have been identified as essential for success in the field of engineering (Brunhaver, Korte, Barley & Sheppard, 2017; Koen & Kohli, 1998; Newport & Elms, 1997; Passow & Passow, 2017), and have been found to be positively associated with poor EF (Boot, Nevicka & Baas, 2017; Taylor, Zaghi, Kaufman, Reis & Renzulli, 2020; 2020ba; Zabelina, Condon & Beeman, 2014). Although the direct association between divergent thinking and academic achievement is modest (Gajda, Karwowski & Beghetto, 2017), the potential role of divergent thinking as a buffer against poor academic achievement for those with poor EF has not been examined. Thus, the present study examines divergent thinking as a moderating variable in the relationship between EF and academic achievement in undergraduate engineering students.

1.1. Executive functioning and college success

EF encompasses the self-directed cognitions and actions that are crucial for college success, such as time management, organization, motivation, self-restraint, and emotional regulation (Barkley, 1997). The ability to manage one's time is necessary to meet course and university deadlines and is directly related to academic performance (Britton & Tesser, 1991). Likewise, the ability to organize and prioritize competing demands is an essential skill for academic success and related behaviors, such as setting appropriate academic goals, have been found to enhance students' academic performance (e.g., Morisano, Hirsh, Peterson, Pihl & Shore, 2010). For example, setting explicit goals for grades was found to be the second strongest non-intellectual indicator of college GPA (after performance self-efficacy) in a meta-analysis examining 42 such constructs (Richardson, Abraham & Bond, 2012). Effort regulation, the ability to persist in the face of academic challenge, was also strongly associated with GPA (Richardson et al., 2012). Another meta-analysis also found that academic motivation was strongly associated with GPA (Robbins et al., 2004). Self-restraint, or inhibition, is vital to completing academic requirements, as college students frequently encounter situations they must resist because they are in conflict with their academic goals (see Duckworth, Taxer, Eskreis-winkler, Galla & Gross, 2019). Emotional regulation and the emotions one experiences may primarily interact with – or work through influencing – other components of EF, such as self-restraint and motivation, to impact academic achievement (Daniels et al., 2009; Garg, Levin & Tremblay, 2016; Mega, Ronconi & De Beni, 2014; Villavicencio & Bernardo, 2013). Even seemingly small study habits and skills, such as completing assigned class reading or minimizing distractions while studying, requires multiple abilities that rely on EF (e.g., organizational skills and sustaining attention). Thus, it seems clear that EF is instrumental to college success.

Accordingly, *poor* EF has been found to be associated with lower academic achievement and poorer study habits and skills in adults (Biederman et al., 2006; Munro, Weyandt, Marraccini & Oster, 2017; Norwalk, Norvilitis & MacLean, 2009; Petersen, Lavelle & Guarino, 2006). Biederman et al. (2006) found that adults with EF deficits, determined using a series of cognitive tasks, had lower academic achievement compared with adults without EF deficits. Norwalk et al. (2009) found that college students' inattentive symptoms on a self-report scale of Attention Deficit Hyperactive Disorder (ADHD) negatively predicted academic adjustment, such as how well a student copes with academic demands. Students who scored higher on inattentive symptoms also reported poorer study habits and skills, such as not completing assigned class reading or watching TV while studying. Moreover, poor EF is negatively associated with many of the factors critical for college success highlighted above. For instance, poor EF in college students predicts procrastination (i.e., intentionally delaying due tasks; Rabin, Fogel & Nutter-Upham, 2011; Rinaldi, Roper & Mehm, 2019), which is in turn associated with lower test performance (Moon & Illingworth, 2005). Knouse, Feldman and Blevins (2014) found that of the five components of EF assessed by the Barkley Deficits in Executive Functioning Scale (BDEFS; Barkley), motivation most strongly predicted the cumulative GPA of undergraduate students. Although educational difficulties associated with poor EF apply broadly to university settings, some educational programs, such as engineering, may be particularly demanding for those with poor EF.

Although research in this area is limited, the structure of post-secondary engineering education may be particularly difficult for those with poor EF. Engineering education continues to be based predominantly on a traditional teaching paradigm, in which most non-lab courses are taught by lecture and heavily emphasize memorizing facts and formulas (Cropley, 2015a; Felder, 2012, 2021). Engineering course assignments and exams have also been suggested to rely primarily on the application of previously encountered concepts in solving well-defined problems (Rugarcia et al., 2000). Students who have difficulty regulating time, attention, and motivation may be particularly susceptible to disengagement with this type of coursework. This is not to suggest that these issues exist in all engineering courses or that they are non-existent in non-engineering courses. Indeed, any heavily structured course using a passive learning approach focused on memorization is likely to be more difficult for students with poor executive functioning. However, post-secondary engineering programs tend to have a higher proportion of courses with this structure when compared to programs in other fields, such as the humanities, arts, and social sciences. The results of a survey of over 10,000 faculty members across 109 post-secondary institutions in the United States showed that a cluster of engineering faculty ($N = 496$) reported emphasizing deep learning approaches (approaches to learning that emphasize integration, synthesis, and reflection) the least when compared to clusters of faculty from 62 other fields (Nelson Laird, Shoup, Kuh & Schwarz, 2008). Although active and cooperative learning approaches may be becoming more common in engineering courses, changes have mostly been enacted at the individual course level (Litzinger et al., 2011) and substantial change has yet to be realized (Wankat & Bullard, 2016). In a follow-up to *The Future of Engineering Education* (e.g., Felder, Woods, Stice & Rugarcia, 2000; Rugarcia et al., 2000; Woods, Felder, Rugarcia & Stice, 2000), Wankat and Bullard's (2016) response to whether engineering education reform has been successful was: "Despite new scientific knowledge about both teaching and learning, significant transformation of engineering education remains elusive." (p. 25). Thus, it may be more fruitful to identify and develop students' personal resources that may contribute to their academic success in engineering education.

1.2. Divergent thinking as a potential resource

One potential resource that may help to buffer against the negative effects of poor EF on academic success is divergent thinking. Divergent thinking refers to the generation of many original and diverse responses to a stimulus and is supported by four abilities (Guilford, 1956, 1967). First, fluency is the ability to quickly generate ideas and is typically measured by the number of responses (or the amount of time required to generate a response; see Barbot, 2018). Second, flexibility is the ability to generate diverse ideas and is typically measured by the number of categories in a set of responses. Third, originality is the ability to generate unique responses and is typically measured by the statistical infrequency of a set of responses. Fourth, elaboration is the ability to develop ideas and is typically measured by the amount of detail provided for responses. Although convergent thinking, narrowing down ideas and solutions by discarding inappropriate or less desirable ones, also plays a critical role, solving novel problems depends heavily on divergent thinking ability (Guilford, 1987). Divergent thinking ability has also been found in previous studies to be positively associated with poor EF in adults (Boot et al., 2017; Taylor et al., 2020a, 2020b; Zabelina et al., 2014). Thus, divergent thinking may be a personal resource that can be drawn on for those with poor EF.

Creativity, of which divergent thinking is a core component (Reiter-Palmon, Forthmann & Barbot, 2019), has already been recognized as an essential skill in the field of engineering (Brunhaver et al., 2017; Cropley, 2015a; Dekker, 1995; National Academy of Engineering, 2005; Passow & Passow, 2017). More than 15 years ago, the National Academy of Engineering explicitly identified creativity as a key attribute for engineering graduates in 2020 (National Academy of Engineering, 2004). Practicing engineers and employers frequently identify creativity-related skills (e.g., creativity, innovation, lateral thinking) as essential for new engineering graduates to possess (Hirudayaraj et al., 2021; Passow & Passow, 2017). Scholars emphasize the importance of these skills for solving the ambiguous, multifaceted, and interdisciplinary challenges that modern engineers face, as well keeping up with the rapid pace of innovation and changes in the workplace (Brunhaver et al., 2017; Cropley, 2015a, 2015b). However, there appears to be a disconnect between the role creativity related skills, such as divergent thinking, play in the field of engineering and how they relate to academic achievement.

Despite theoretical suggestions that creativity and related skills enhance academic achievement (e.g., Beghetto & Karwowski, 2018), empirical work demonstrating this is relatively rare (see Kaufman, 2018b). A meta-analysis of studies examining the association between academic performance and creativity, which consisted primarily of divergent thinking tasks, found that the relationship explained only 5% of variance (Gajda et al., 2017). Moreover, this relationship was significantly weaker when GPA was used as the indicator of academic achievement compared to performance on academic tests. Indeed, Taylor et al. (2020b) found that engineering GPA was not significantly associated with divergent thinking scores. Atwood and Pretz (2016) found that engineering GPA was not significantly associated with divergent thinking scores or the creativity of responses on tasks asking students to write a caption for an ambiguous photograph or a short essay. However, studies examining the consequences of including scores on assessments of creativity as part of the admissions process, have found that creativity predicts academic success in college beyond traditional standardized tests (see Sternberg, 2018). It is possible for divergent thinking to demonstrate only a weak *direct* association with academic achievement in general, yet still play a significant role in academic success, particularly if it serves as a compensating factor. However, divergent thinking as a potential buffer in the relationship between poor EF and academic achievement has yet to be explored.

1.3. The present study

The present study examined the role of divergent thinking in the association between EF and GPA in engineering education. We expected to find a negative association between poor EF and engineering GPA, consistent with previous studies using both general college (Knouse et al., 2014) and engineering (Taylor et al., 2020b) student samples. We further expected that the association between EF and GPA would be moderated by divergent thinking, such that the negative association would be weaker for those with relatively higher divergent thinking scores. Because performance on divergent thinking tests is stimulus-dependent (Barbot, 2018, 2016), we included measures of both figural and verbal divergent thinking ability.

2. Method

This study was approved by the Institutional Review Board at the University of Connecticut (protocol #H17-196).

2.1. Participants

Undergraduate engineering students at a public university in the United States were recruited with flyers and emails sent to their student account. A total of 220 participants completed the study. Data for participants who withdrew from the study ($N = 20$) or were not eligible for participation[2] ($N = 1$) were discarded. The resulting sample of 199 participants (56.3% men, 43.7% women) ranged in age from 18 to 33 years old ($M = 19.89$, $SD = 1.86$). Participants' grade level classification was distributed as follows: 32 sophomores, 49 juniors, and 118 seniors. Participants were compensated with a $35 gift card (prorated at $8.75 per session) after completing or withdrawing from the study.

2.2. Materials

2.2.1. Barkley deficits in executive functioning scale (BDEFS)

The BDEFS (Barkley) contains 89 self-report items reflecting behaviors that represent five dimensions of deficits in EF (i.e., time management, self-motivation, self-restraint, self-organization/problem-solving, and self-regulation of emotion). Participants indicate, on a scale from 1 (never) to 4 (very often), how often they have experienced each observable behavior (e.g., "*have trouble doing things in their proper order or sequence*" and "*likely to do things without considering the consequences for doing them*") within the previous six months. Items corresponding with the five dimensions are summed to obtain subscale scores. A total scale score, reflecting poorer overall daily EF, is obtained by summing the scores across all subscales. In the current study, the BDEFS total scale score exhibited strong internal consistency reliability (Cronbach's $\alpha = 0.96$).

The scale, developed and validated using a nationally representative sample of adults in the United States (Barkley), was designed to assess EF impairments associated with ADHD. However, recent studies have provided evidence that the scale can be used to validly assess EF in non-clinical samples, including in 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 United States (Kamradt et al., 2019).

2.2.2. Torrance tests of creative thinking (TTCT)

Form A of the TTCT-Verbal and Form A of the TTCT-Figural (Torrance, 2008) were used to assess divergent thinking. The TTCT-Verbal test contains five activities that require a written response (e.g., providing as many creative uses for a cardboard box as possible). Participants were given a time limit (ranging from 5 to 10 min) to complete each task, in accordance with the testing manual instructions. Responses to each task on the TTCT-Verbal were scored by three trained and certified raters at Scholastic Testing Services (STS) on three dimensions: fluency (total number of responses), originality (infrequency of responses), and flexibility (variability in categories of responses). Scores demonstrated strong inter-rater reliability across the three raters, according to Cronbach's α (fluency = 1.00, originality = 1.00, and flexibility = 0.98), and were averaged to create total dimension scores for each participant. Dimension scores on the TTCT-Verbal test demonstrated strong internal consistency (Cronbach's $\alpha = 0.91$) and were strongly, positively correlated with one another ($r = 0.86$ to 0.98). Total scores were created for the TTCT-Verbal by averaging the scores for each dimension (after z-transformation based on the sample, to account for differing rating scales).

The TTCT-Figural test contains three drawing activities (e.g., providing as many creative pictures from a series of parallel lines as possible). Participants were given a time limit of 10 min to complete each task. Responses to each of the TTCT-Figural tasks were by three trained and certified raters at Scholastic Testing Services (STS) on five dimensions: 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). Scores demonstrated strong inter-rater reliability across the three raters, according to Cronbach's α (fluency = 0.99, originality = 0.99, elaboration = 0.98, resistance to premature closure = 1.00, titles = 0.99), and were averaged to create total dimension scores for each participant. Dimension scores on the TTCT-Figural demonstrated acceptable internal consistency (Cronbach's $\alpha = 0.76$) and were also significantly, positively correlated with one another (albeit with several weaker correlations; $r = 0.18$ to 0.64). Total scores were created for the TTCT-Figural by averaging the scores for each dimension (after z-transformation based on the sample, to account for differing rating scales).

2.3. Procedure

Participants completed four separate study sessions in a private office on different days, lasting approximately 30–60 min each. Participants completed the TTCT-Figural test, after informed consent, in the first session of testing. 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 . During the third session, all activities and tasks participants completed were for use in a different study. During the fourth session, participants completed the TTCT-Verbal test. Cumulative engineering GPA was prov1ided by the university's Office of the Registrar following completion of the study.

3. Results

3.1. Preliminary analyses

Data for two outliers (> ± 3.5 SD from the mean) were removed from the BDEFS scale score. Gender differences on the primary

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

variables were examined with a series of independent *t*-tests. No significant mean gender differences were found on any variable (with Bonferroni corrected α = 0.01): engineering GPA [$t(197) = -1.05$, $p = .29$], TTCT-Verbal [$t(197) = -2.42$, $p = .02$], TTCT-Figural [$t(197) = -1.60$, $p = .11$], and BDEFS [$t(195) = 1.38$, $p = .17$]. Additionally, Levene's test for equality of variances did not indicate differences in the variability of men's and women's scores for any variable: engineering GPA [$F(197) = 1.04$, $p = .84$], TTCT-Verbal [$F(197) = 0.43$, $p = .51$], TTCT-Figural [$F(197) = 0.88$, $p = .35$], and BDEFS [$F(195) = 0.28$, $p = .60$]. Differences between grade levels (sophomore vs. junior vs. senior) were examined using a series of one-way ANOVAs. Students at different grade levels did not differ significantly on any variable: engineering GPA [$F(2, 196) = 1.55$, $p = .22$], TTCT-Verbal [$F(2, 196) = 1.35$, $p = .26$], TTCT-Figural [$F(2, 196) = 0.13$, $p = .88$], and BDEFS [$F(2, 194) = 0.99$, $p = .37$]. Thus, all subsequent analyses were conducted for the sample as a whole. Descriptive statistics and bivariate correlations amongst the variables may be seen in Table 1 and a scatterplot matrix may be seen in Fig. 1.

3.2. Multiple moderation model

The PROCESS macro for SPSS (Hayes, 2018) was used to test a multiple moderation model to determine if verbal and figural divergent thinking moderated the relationship between EF and engineering GPA ($r = -0.18$, $p = .01$). The relationship between EF and engineering GPA was significantly moderated by figural TTCT scores (holding verbal TTCT scores constant), $F(1, 191) = 4.70$, $p = .03$, $\Delta R^2 = 0.02$. However, verbal TTCT scores were not a significant moderator (holding figural TTCT scores constant), $F(1, 191) = 0.07$, $p = .79$, $\Delta R^2 = 0.00$ (Table 2). At low levels of EF problems, GPA was similar regardless of either verbal or figural divergent thinking ability. However, as levels of EF problems increased, GPA declined for those with relatively lower figural divergent thinking scores and did not change for those with relatively higher scores (Fig. 2). A region of significance test (also known as the Johnson-Neyman technique; Bauer, Curran & Thurstone, 2005; Hayes, 2018) demonstrated that poor EF was significantly associated with declines in GPA only for those with figural divergent thinking scores below 0.21, corresponding with 63.96% of the sample (Fig. 3).

4. Discussion

The current study examined the role of verbal and figural divergent thinking in the relationship between overall daily EF and engineering GPA. As expected, scores on the BDEFS, reflecting overall daily EF, were significantly negatively correlated with engineering GPA. Additionally, as expected, we found that figural (though not verbal) divergent thinking significantly moderated this relationship. A greater frequency of behaviors reflecting poorer overall daily EF was associated with lower GPA for those with relatively lower figural divergent thinking ability only. Thus, our results suggest that the relation between overall daily EF and engineering GPA may depend on other personal resources, such as figural divergent thinking.

4.1. Theoretical implications

Our results showed that BDEFS scores were associated with the academic achievement of engineering students in similar ways to previous research conducted with general student populations. The bivariate correlation between BDEFS scores and engineering GPA in our study was identical in direction and strength to that found for general cumulative GPA in two samples of undergraduate students using the short-form of the BDEFS (i.e., -0.18; Knouse et al., 2014). Thus, although it has been suggested that engineering education and other STEM fields may be more demanding for those with poor EF (e.g., Taylor et al., 2020b), our results may generalize to academic areas outside of engineering more so than previously thought.

Our results support the notion of divergent thinking as a personal resource that may be leveraged in engineering education for those with poor EF. As such, our results contribute to emerging work showing the importance of components of creativity in everyday life (e.g., Forgeard & Kaufman, 2015; Kaufman, 2018). However, the underlying mechanism by which divergent thinking moderates the association between EF and GPA can only be speculated at this point. Consistent with evidence that divergent thinking is related to fluid intelligence (Beaty, Silvia, Nusbaum, Jauk & Benedek, 2014; Nusbaum, Silvia & Beaty, 2014; Silvia, 2008), it may be that students with greater divergent thinking ability are able to perform better on course assignments and tests due to greater memory retrieval ability. This type of compensating effect of IQ has been shown in individuals with ADHD, for whom problems with EF may be severe (Barkley, 1997; Hervey, Epstein & Curry, 2004; Willcutt, Doyle, Nigg, Faraone & Pennington, 2005). For example, Milioni et al. (2017) found that individuals with ADHD performed similarly to those without ADHD on a series of in-lab EF tasks when they had high – as opposed to more average – IQ scores. However, divergent thinking ability may also compensate for specific behaviors assessed by the BDEFS that are related to poor academic performance. For instance, the ability to quickly generate ideas may be beneficial for those who have trouble managing their time and motivation. A student who must complete an assignment at the last minute due to ineffective time management may be more likely to finish the task and receive a better grade if they are able to generate ideas and solutions for the assignment more quickly.

However, it remains unclear if our finding, that figural – but not verbal – divergent thinking was a significant moderator, would generalize to academic areas outside of engineering. Although both forms of the TTCT assess ideational ability, scores on divergent thinking tasks are known to be influenced by domain and task specific skills and expertise (Barbot, 2018; Clapham, 2011). Performance on the figural form draws on a different skill set than the verbal form (Cramond, Matthews-Morgan, Badnalos & Zuo, 2005) and may better relate to achievement in STEM fields such as engineering. For example, visual-spatial skills have been identified as being particularly important for success in engineering and other STEM fields (Humphreys, Lubinski & Yao, 1993; Sorby, Duffy, Loney & Perez, 2018). Additionally, problems with EF have been found to be associated with greater problems with verbal (compared to

Table 1
Descriptive statistics and bivariate correlations.

Variable	1	2	3	4
1. Engineering GPA	–			
2. TTCT Figural	.14	–		
3. TTCT Verbal	.06	.44**	–	
4. BDEFS	-.18*	-.02	-.12	–
N	199	199	199	197
Mean	3.26	0.00	0.00	156
SD	.56	.72	.97	32.29
Min. - Max.	1.10–4.00	-1.76–2.25	-2.25–2.92	98–245

Note. TTCT verbal and figural scores are averaged z-scores of corresponding subscales; TTCT = Torrance Tests of Creative Thinking; BDEFS = Barkley Deficits in Executive Functioning Scale.
* $p < .05$
** $p < .01$.

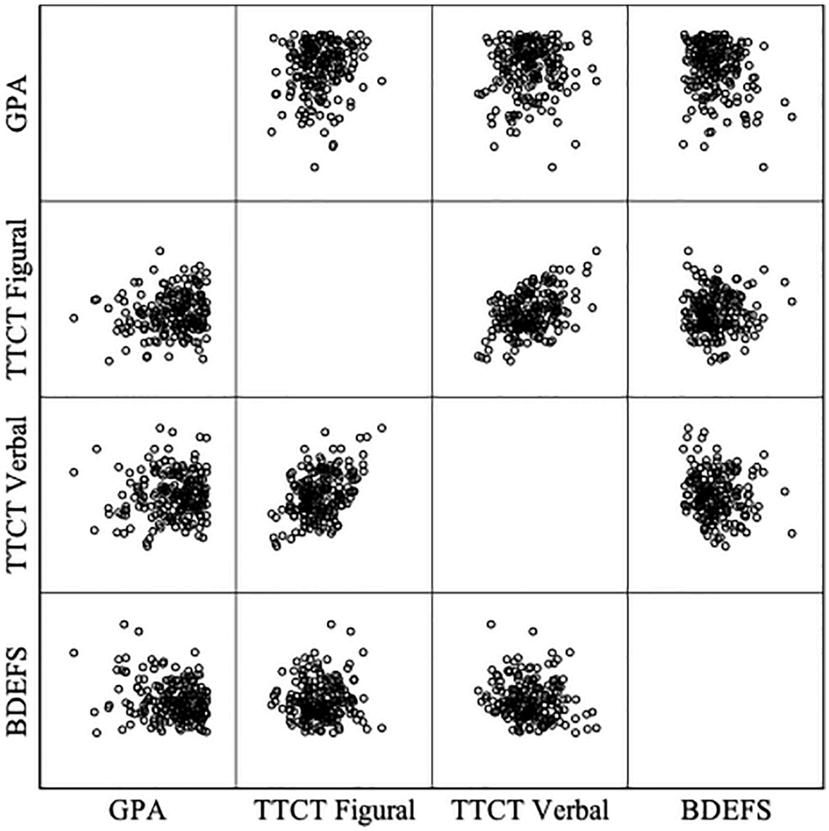

Fig. 1. Scatterplot matrix of variables included in analyses.

visual-spatial) abilities, such as reading comprehension (Follmer, 2018).[3] Although bivariate correlations between other variables and both the TTCT figural and verbal were small and not statistically significant, there was a trend such that figural TTCT scores were more positively associated with engineering GPA, whereas verbal TTCT scores were more negatively associated with BDEFS scores. Whether

[3] At the request of an anonymous reviewer, we conducted a supplementary analysis to examine whether our results could be explained by visual-spatial ability alone by including scores on the matrices subtest of the Kaufman Brief Intelligence Scale 2 (KBIT-2; A. S. Kaufman & Kaufman, 2004) and figural TTCT scores as moderators in a multiple moderation model. The matrices subtest (assessed for use in a different study; redacted for blind review), contains 46 items requiring participants to indicate which of five pictures corresponds with a concept conveyed by a figural stimulus or which of six pictures completes a presented matrix. Results showed that the relationship between EF and engineering GPA continued to be significantly moderated by figural TTCT scores controlling for matrices scores, $F(1, 190) = 4.30$, $p = .04$, $\Delta R^2 = .02$, whereas matrices scores were not a significant moderator controlling for figural TTCT scores, $F(1, 190) = .40$, $p = .53$, $\Delta R^2 = .00$.

Table 2
Coefficients for multiple moderation model.

Model	Coeff.	SE	*t*	*p*	95% CI
Constant	3.78	.20	19.36	.00	3.39, 4.17
BDEFS (X)	.00	.00	-2.65	.01	-0.01, 0.00
Figural DT (W)	-0.50	.30	-1.68	.10	-1.09, 0.09
Verbal DT (Z)	0.02	.22	0.10	.92	-0.41, 0.46
BDEFS x Figural DT (XW)	.00	.00	2.17	.03	.00, 0.01
BDEFS x Verbal DT (XZ)	.00	.00	-0.26	.79	-0.00, 0.00
	F (5, 191) = 3.50, p < .001, R^2 = 0.08				
	ΔF (2, 191) = 2.85, p = .06, ΔR^2 = 0.03				

Note. BDEFS = Barkley Deficits in Executive Functioning Scale (Barkley); DT = divergent thinking; *F* change values reflect the addition of both moderators into the model.

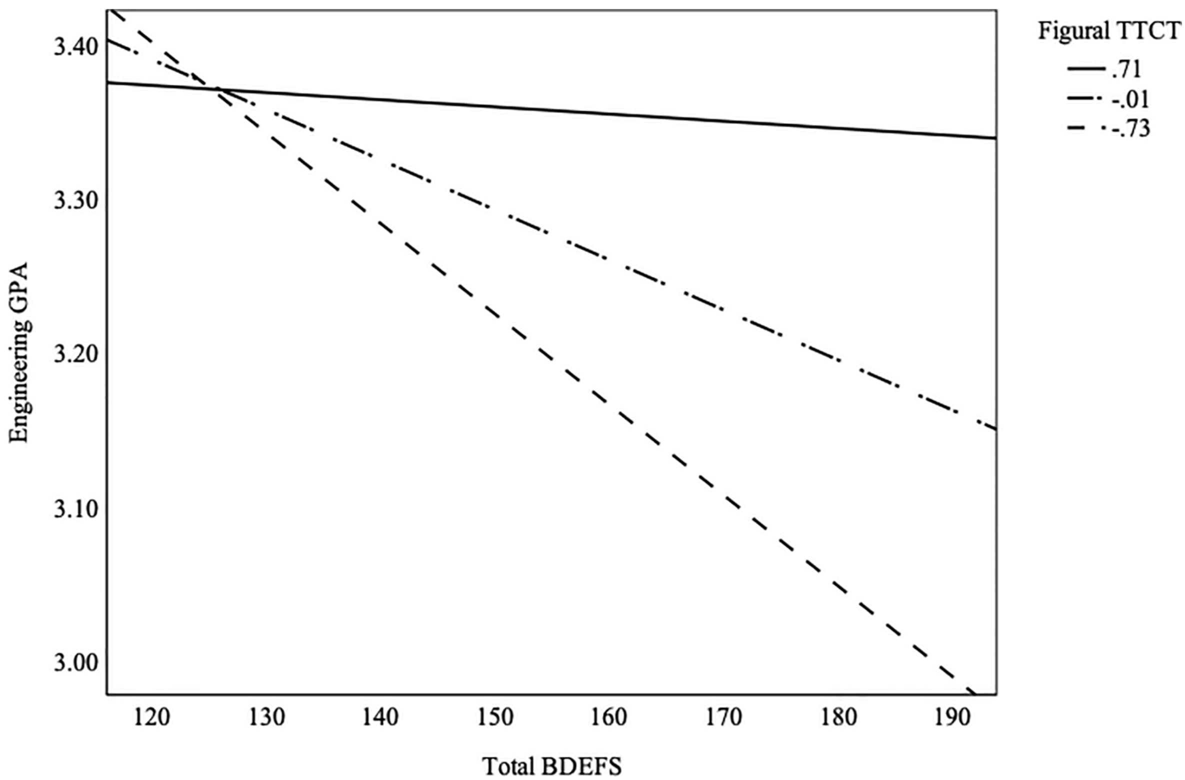

Fig. 2. Visual representation of engineering GPA at different levels of Figural TTCT scores across BDEFS scores. *Note.* Figure is based on the pick-a-point approach, wherein line was fitted to means for each group at the mean and ± 1 SD of BDEFS scores (for which higher scores reflect poorer EF). Please note that both axes are truncated and do not reflect the full range of scores.

or not the finding that the TTCT figural – but not verbal – moderated the association between EF and GPA due to characteristics unique to STEM fields would be easy enough to establish by conducting these analyses with data from participants in other academic areas.

4.2. Practical implications

Although GPA is only one indicator of academic success, it weighs heavily in decisions that influence ones' opportunities, such as admission to graduate school (Chari & Potvin, 2019; Kuncel, Ones & Hezlett, 2001; Stemler, 2012). However, undergraduate GPA may not accurately predict later success in the field of engineering. Meta-analytic evidence shows that undergraduate GPA is not strongly associated with either success in graduate school or indicators of later workforce success, such as salary, promotions, or job performance (Bretz, 1989; Samson, Graue, Weinstein & Herbert, 1984). Samson et al. (1984) found that undergraduate GPA was less predictive of occupational performance in engineering than in other fields, such as business or nursing. Abilities related to divergent thinking, however, are increasingly identified as being essential for success in the field (Brunhaver et al., 2017; Koen & Kohli, 1998; Newport & Elms, 1997). For example, Passow and Passow (2017) found that working engineers used terms such as "creative thinking," "innovation," and "lateral thinking" when describing the competencies that all new graduates should possess in 20 out of 25 qualitative

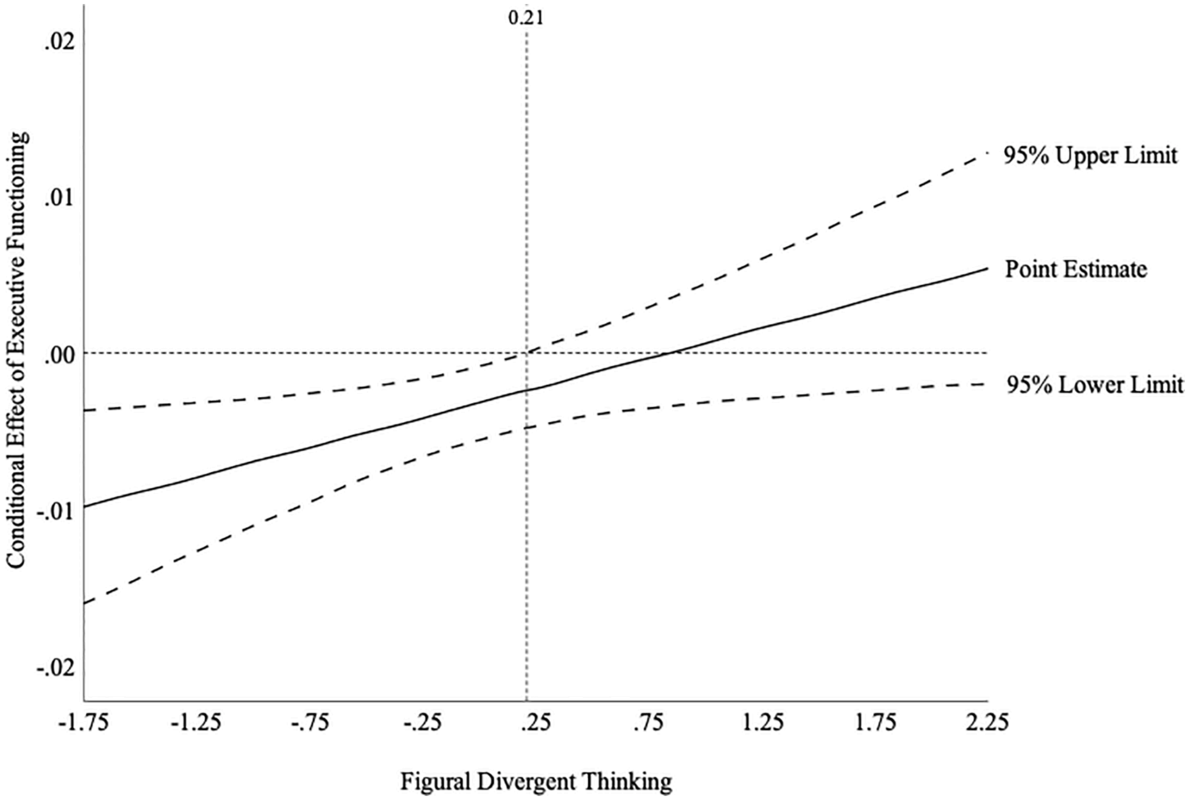

Fig. 3. The conditional effect of executive functioning scores on engineering GPA as a function of figural divergent thinking.

studies reviewed. In quantitative analyses, the ability to think creatively also emerged as one of the eight competencies that distinguish between outstanding and ordinary engineers (Passow & Passow, 2017).

Thus, our results highlight divergent thinking training as a potential opportunity for enhancing both GPA and later success in the field for those with poor EF. Although divergent thinking ability is often construed as a static, trait-like, individual difference, there is strong evidence that divergent thinking within a given domain can be enhanced through training (see Scott, Leritz & Mumford, 2004). Training programs developed specifically to enhance creativity in engineering have been successful in enhancing scores on psychometric assessments of creativity (Clapham & Schuster, 1992) and the creativity of engineering products (Cropley & Cropley, 2000). However, how these programs influence other factors, such as academic success, has not yet been examined and requires further research.

4.3. Limitations and recommendations for future research

In addition to the research directions suggested above, there are several limitations in the current study that may be addressed in future research. Although self-report scales of EF have been shown to be valid indicators of impaired functioning in both clinical and non-clinical samples (e.g., Biederman et al., 2007), scales based on self-report are frequently criticized. This is, in part, because they are vulnerable to being influenced by several well-established biases (Fryer & Dinsmore, 2020; Paulhus and Vazire, 2005). Future studies may also include reports of participants' behavior by those close to them, by using the informer-report scale of the BDEFS (Barkley). This type of multi-informant assessment approach is common in the psychological sciences, but results should be interpreted with care (see De Los Reyes, Thomas, Goodman, & Kundey, 2013).

Although performance on lab-based EF tasks may also be informative, it is important to note that scores on EF tasks and self-report scales are rarely associated with one another (e.g., Kamradt, Ullsperger & Nikolas, 2014; Toplak, West & Stanovich, 2017). Lab-based tasks of EF are used to assess narrow EF abilities, such as the ability to inhibit prepotent responses on the Flanker task (Eriksen & Eriksen, 1974) or continuously update working memory on N-back tasks (Owen, McMillan, Laird & Bullmore, 2005). However, these tasks have also been criticized, primarily for being contaminated by general cognitive ability and other cognitive processes not reflecting EF (Biederman et al., 2008; Burgess et al., 2006). Although there are unique drawbacks and benefits to each type of assessment, self-report measures have been suggested to have better ecological validity than lab-based tasks (e.g., Barkley & Murphy, 2011). However, including both lab-based and self-report measures in future research may help to uncover how specific cognitive processes relate directly to more practical compensation efforts (e.g., faster completion of projects after procrastination).

5. Conclusion

Our results suggest that engineering GPA for students who have few problems with overall daily EF may be unaffected by their divergent thinking ability. However, figural divergent thinking was associated with enhanced engineering GPA for students with relatively poorer EF. Although GPA may not be a strong predictor of career success in the field of engineering (Bretz, 1989; Samson et al., 1984), it does influence who remains in engineering education (Zhang, Min, Ohland & Anderson, 2006) and who is able to pursue higher levels of training (e.g., Chari & Potvin, 2019). Thus, given the importance of divergent thinking and related abilities in the field (e.g., Passow & Passow, 2017), supporting divergent thinking in engineering education may support the participation of traditionally underrepresented populations (e.g., those with ADHD; Sparks, Javorsky & Philips, 2004) *and* contribute to the later career success of engineering students in general. Although more research is needed to support these claims, this study represents an important first step by demonstrating that divergent thinking can be leveraged to enhance academic achievement in engineering students with poor EF.

CRediT authorship contribution statement

Christa L. Taylor: Conceptualization, Methodology, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **Arash E. Zaghi:** Conceptualization, Methodology, Investigation, Resources, Writing – review & editing, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors have no conflicts of interest to disclose.

Data Availability

Data will be made available on request.

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