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Domain-specific and Domain-general Creativity Differences between Expert and Novice Designers

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ABSTRACT

Creativity is not only a natural part of the design process but also one of the most important criteria for the quality of design performance. However, the difference in creativity between design novices and experts remain to be explored. To explore this question, this study compared the differences in domain-specific and domain-general creativity between design (as expert) and non-design students (as novice) and test the mediating effect of domain-general creativity on the relationship between group (design vs. no-design) and domain-specific creativity. The results revealed that design students exhibited better domain-general creativity performance (both verbal and visual divergent thinking) than non-students. Moreover, design students also exhibited better domain-specific creativity performance than non-design students in both "originality" (i.e. novel) and "amenity" (i.e. beauty appreciation), and the factor of GROUP (design vs. non-design) first influenced domain-general creativity and then domain-specific creativity. These findings suggest that training visual divergent thinking skills may be one pathway to improving design creativity.

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Introduction

Design thinking is generally defined as an analytic and creative process that engages a person in opportunities to experiment, create and prototype models, gather feedback, and redesign (Razzouk & Shute, 2012). From the perspective of design cognition, design activity can be frequently described as an "ill-defined problem" or "wicked problem" for which many possible solutions exist and there are no clear rules to define inferiority and superiority (Cagan, Kotovsky, & Simon, 2001; Goldschmidt, 1997; Rittel & Webber, 1973). In recent years, there has been a rapid growth in studies on design cognition comparing the cognitive differences between expert and novice designers, including knowledge structure or mental presentation (Bjorklund, 2013; Popovic, 2004), cognitive strategies and analogical reasoning (Casakin, 2010; Casakin & Goldschmidt, 1999; Cross, Christiaans, & Dorst, 1994; Kim, 2010; Kruger & Cross, 2006; Lawson, 1979), "design fixations" (Crilly, 2015; Crilly & Cardoso, 2017), and design creativity (Bhattacharya & Petsche, 2005; Edl, Benedek, Papousek, Weiss, & Fink, 2014; Kowatari et al., 2009).

Creativity is not only a natural part of the design process but also one of the most important criteria for the quality of design performance and is often described as a leap between the problem and the solution space (Demirkan, 2010). It refers to the ability to produce novel and appropriate ideas or products through a series of cognitive processes (Lubart & Sternberg, 1995). Divergent thinking is regarded as a critical component of creative thinking (Runco, 2010). Whether creativity is domain-general or domain-specific is one of the most enduring controversies in the field. Some scholars believe that creativity is a domain-general ability (Plucker, 1998) and suppose that creativity in different domains involves similar creative thinking processes, such as divergent thinking. Creative performance in various areas could be enhanced by training these basic creative processes. Other scholars propose the domain-specificity perspective (Baer, 1998, 2012), supposing that creativity in different domains (e.g., design creativity) involves a diversity of knowledge, creative thinking skills, dispositions, or tendencies (Baer, 2010). Recently, increasing studies have suggested that creativity can be viewed as both domain-general and domain-specific (Kaufman & Sternberg, 2010). For example, one study found the relation between domain-general creative thinking performance and mathematical creative thinking performance was positive and unidirectional from general to specific creative ability (Milgram & Livne, 2005). The correlations between domain-general creative performance with domain-specific

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creative performance in the literature (Hong & Milgram, 1996) and architecture (Casakin, Davidovitch, & Milgram, 2010) were also statistically significant and moderate in size.

In some sense, the designer is like a creative problem solver. However, do design experts or design major students exhibit better design creativity and domain-general creativity than novices? Simon's work on intuition and expertise concluded that the expert exhibits "usual appearance of intuition," while the novice uses "conscious and explicit analysis." That is, experience allowed experts to make decisions intuitively or judgments "without careful analysis and calculation" (Simon, 1996). Johnson-Laird's work on improvisation and mental models assumed that theories of creativity should be computable and creativity was specific to a particular domain of expertise (Johnson-Laird, 2002). Ozkan and Dogan (2013) investigated the difference in analogical reasoning of design among first, second, and fourth-year students and expert architects. They concluded that the experts preferred "mental hops" (i.e. creativity is associated with analogies to near-source domains and results in incremental innovation), while the first-year students preferred'mental leaps' (i.e. creativity is associated with establishing relationships to remote source domains that are difficult to bring to mind). Edl et al. (2014) found that design students attained higher scores in verbal and visual divergent thinking tasks than students of other majors. Studies also revealed that visual art learning or design training altered neural structures and functions (Bhattacharya & Petsche, 2005; Ellamil, Dobson, Beeman, & Christoff, 2012; Kowatari et al., 2009; Saggar et al., 2017; Schlegel et al., 2015). Kowatari et al. (2009) compared the differences in brain activity between design experts and novices when designing a new tool. The results showed that in the experts, the creative performance was significantly correlated with a high degree of activity in the right prefrontal cortex. In contrast, in the novices, only a negative correlation with creativity in the bilateral inferior parietal cortex was observed. Saggar et al. (2017) examined longitudinal changes in brain activity in participants after taking part in a five-week design-thinking-based training compared with language control training. It was found that improvisation-based creative capacity enhancement was associated with the reduced engagement of executive functioning brain regions and increased involvement of spontaneous processing in the design training groups. These findings were consistent with previous studies of prefrontal mediating inhibition, evaluation, working memory, and visual imagery processes (Pidgeon et al., 2016).

Previous studies also examined how design education could assist in the transition from novice to expert (Eastman, McCracken, & Newstetter, 2001). Lawson (1979) compared the design approaches of engineering students to architecture students and found that different educational priorities led to different design strategies. Atman, Chimka, Bursic, and Nachtmann (1999) found that senior engineering students produced higher-quality designs, gathered more information, and considered more alternative solutions compared to the freshmen. Changes in individual students' behaviors over time can be quite complex and variable (Atman, Cardella, Turns, & Adams, 2005). Schon and Goldschmidt also provided an extensive contribution showing how the dialectic relationships within a studio environment can improve design performance (Goldschmidt, 1991; Schön, 1984, 1992).

Thus, these previous studies have revealed that design experts or design major students may exhibit better domain-specific creativity (design creativity) and domain-general creativity than novices (Bhattacharya & Petsche, 2005; Edl et al., 2014; Kowatari et al., 2009). However, the structure of design creativity, especially the expert-novice difference in this structure, remains unclear. According to one study by Barron (1955), a creative output must be original. It can also be generally characterized by "elegance" or "aesthetic fit" (Barron, 1969). In this study, we addressed three questions: (1) Did design expert and novice differ in domain-general creativity and design creativity? (2) Did design training enhance design creativity through the "originality" pathway (i.e., novel) or "amenity" pathway (i.e., beauty appreciation), or both? In this study, the "originality" pathway included elements such as appearance novelty and imagination and the "amenity" pathway included elements such as elaboration and likability. Additionally, a close association between the domain-general and domain-specific creative performance has been observed in architectural design (Casakin et al., 2010), whereas no such correlation has been observed in engineering design (Charyton & Merrill, 2009). These findings emphasized the necessity of considering the relationship between domain-general and domain-specific creativity when studying different design areas. Therefore, the third question was: (3) Was the effect of design training (expert vs. novice) on individual design creative performance ("originality" aspect, "amenity" aspect and overall performance) through domain-general creativity?

To this end, this study aimed to answer these questions by comparing the creativity task performances of design students with non-design students. Because recruiting enough design experts is of highly challenge, "design students" with more than two years of design training were recruited as the design expert and "non-design students" as the design novice. First, the differences between the two groups in domain-general creativity (verbal and visual divergent thinking) were compared. Second, the difference between design students and non-design students in design creativity was compared through a product design task and a book cover design task, including "originality" and "amenity." In addition, the relations among GROUP (design vs. non-design), domain-general creativity and design creativity were examined in a comprehensive model. Our study hypotheses were as follows: (1) Design students will exhibit better visual and verbal divergent thinking performance than non-design students. (2) Design students will exhibit better design creativity than non-design students, both in "originality" and "amenity." (3) Design training will enhance design overall performance through the "originality" pathway and "amenity" pathway. (4) Divergent thinking skills will effectively mediate the relationship between GROUP (design vs. non-design) and design creativity ("originality," "amenity" and overall performance).

Methods

Participants

Seventy-one undergraduates participated in this study, including 35 design students (33 females; *age*: 21.86 ± 2.36 years) and 36 non-design students (29 females; *age*: 21.20 ± 1.43 years). The design students were at least a sophomore student in design and the non-design students were at least a sophomore in another major unrelated to art. Participants belonging to the "design group" had received more than two years of design training at college and completed at least one-year art training before college. Participants belonging to the "non-design group" did not have any training in art nor showed any particular interest in visual art. All participants were recruited through school-wide online advertising. They were all right-handed, with normal or corrected-to-normal vision. Each participant was paid ¥40 for their participation. Informed consents were obtained from participants prior to the experiment. The study procedure was approved by the University Committee on Human Research Protection.

Experimental tasks and procedure

The alternative uses task (AUT; Guilford, 1967) was used to assess verbal creative performance. It required participants to generate as many unusual and original uses as possible for common objects. The AUT is a well-established divergent thinking task (Guilford, 1967; Runco, 1991; Runco & Mraz, 1992). Performance on this task has been demonstrated to be a reliable predictor of creative potential (Runco & Acar, 2012).

The visual divergent thinking test in this study was adapted from the Picture Completion task, one of the subsets of the figural version of the Torrance Test of Creative Thinking (TTCT-figural) (Kim, 2017; Rominger et al., 2018). Participants were asked to use four geometric figures (e.g., one circle, one rectangle, and two triangles) to compose meaningful pictures in 5 minutes, and then name their drawings. Each geometric figure could only be used once. The size of the figure can be changed, but the shape of the figure cannot. This task required participants to combine as many unusual and original pictures as possible.

The product design task (adapted from Kowatari et al., 2009) was used to assess design performance. Participants were asked to design an innovative teapot, which could be improved both in function and appearance (perhaps beyond the existing technological level) in 15 minutes. The more creative the products were, the better. The 15 minutes task duration was determined based on the feedback from 10 independent students majoring in psychology. According to the pilot test, 15 minutes was adequate in order to control the length of the whole experiment. Participants received a piece of A4 white paper, a pencil, and an eraser to draw the product. Participants were required to explain their work after completing it and their explanations were videotaped.

The book cover design task (adapted from Ellamil et al., 2012) was also used to assess domain-specific design performance. Participants were asked to read the introduction of the science fiction book *Back to the Ming Dynasty* carefully and then spend 15 minutes creating and designing a cover for the book. The more creative the cover design, the better. The 15 minutes of the task were also determined by a pilot study with 10 psychology major students. Participants received a piece of A4 white paper, a pencil, and an eraser. Participants were required to explain their work after completing the task and their explanations were videotaped.

Participants finished AUT, TTCT-figural, the product design task and the book-cover design task in random order and were given a break after each task. To rule out the contaminant effect of factors such as task engagement on our findings, participants' feelings of depletion, enjoyment, task engagement, and task difficulty were measured after each task by a 7-point Likert scale.

Assessment of performance on AUT and TTCT-figural problems

Participants' performances on AUT problems were measured for fluency and originality (Guilford, 1967; Runco, 1991). Fluency scores were based on the total number of ideas reported. Originality scores were based on an average of scores on the uniqueness of ideas. Each generated idea was rated from 1 (*not original at all*) to 5 (*highly original*) by five trained raters. The inter-rater agreement (ICC = 0.74) of five independent raters was satisfactory. The final originality score of each participant was computed by averaging the ratings of the five raters.

Similarly, participants' performances on TTCT-figural problems were measured for fluency and originality (Torrance, 1987). Fluency scores were based on the total number of pictures combined. Originality scores were based on the averages of the scores for the uniqueness of ideas. Each generated idea was rated from 1 (*not original at all*) to 5 (*highly original*) by four trained raters. The inter-rater agreement (ICC = 0.79) of the four independent raters was satisfactory. The final originality score of each participant was computed by averaging the ratings of the four raters.

Assessment of performance on the product design task

The rating system was based on Amabile's (1982) series of studies on the influence of social conditions on artistic creativity and Ward's (1994) series of studies on creative cognition, and it was discussed with four graduate students majoring in design. The rating system comprised 10 dimensions (see Table 1).

Following the Consensual Assessment Technique (CAT) (Amabile, 1982), three independent raters, each of whom had spent at least five years working in design art, rated each product on a 5-point Likert scale. They were instructed to look at all the designs before starting their evaluations.

Table 1. The rating dimensions of product design task.

dimension	description
1. Functional novelty	the degree to which the function of the design is original/uncommon;
2. Functional usefulness	the degree to which the function of the design is appropriate;
3. Functional fluency	Numbers of new function;
4. Appearance novelty	the degree to which the appearance of the design is original/uncommon;
5. Esthetics	Artistic quality, the beauty and pleasing sensation;
6. Elaboration	the degree to which details of the design is completed;
7. Concept novelty	the "soul" of a design;
8. Imagination	the author's imagination richness;
9. Likability	the degree to which you like it;
10.Overall evaluation	Comprehensive impression.

Table 2. The rating dimensions of book cover design task.

dimension	description
1. Content novelty	original/uncommon, when expressing the meaning of a book, it has a unique and novel perspective;
2. Content appropriateness	the degree to which the book cover accurately expresses the content of the book;
3. Content fluency	the richness of multi-perspective expression of the book theme;
4. Drawing novelty	the novelty of paintings, such as the novelty and uniqueness of painting elements used to express themes, the novelty of artistic expression techniques such as painting style and composition, or others;
5. Esthetics	artistic quality, the beauty and pleasing sensation;
6. Elaboration	the degree to which details of the design is completed;
7. Imagination	the author's imagination richness;
8. Likability	the degree to which you like it;
9. Overall evaluation	comprehensive impression;

Before testing any hypothesis, an inter-judge reliability assessment was needed to determine whether the subjective judgments were made at an acceptable level. Nine of the dimension scores exhibited good inter-rater reliability (ICCs > .60); only the reliability score of functional usefulness (ICC = .47) was too low for further analysis.

Assessment of performance on the book cover design task

The establishment of the rating system was based on Amabile's (1982) series of studies on the influence of social condition on artistic creativity and Ward's (1994) series of studies on creative cognition in discussion with four graduate students majoring in design. The rating system included nine dimensions (see Table 2).

Following the CAT (Amabile, 1982), six independent raters, each of whom had spent at least five years working in design art, rated each product on a 5-point Likert scale. The raters were instructed to look at all the designs before starting their evaluations.

Before testing any hypothesis, an inter-judge reliability assessment was performed to determine whether the subjective judgments were made at an acceptable level. All the indicators were rated by more than three different raters with good inter-rater reliability (ICCs > .60); in particular, the inter-rater agreements for content novelty, content fluency, drawing novelty, elaboration, imagination, likability, and overall evaluation were all above .70.

Results

Group differences in AUT and TTCT-figural

Independent-sample *t*-tests with GROUP (i.e. design vs. non-design) as a between-subject factor were performed on AUT originality and AUT fluency. The resulting *p* values were corrected by the false discovery rate (FDR) method. A significant effect on AUT originality was observed, t (69) = 3.135, p_{corr} = .010, *Cohen's d* = .746. The design group exhibited higher originality than the non-design group (see Figure 1a). However, no significant difference in AUT fluency was observed between the two groups, t (69) = .261, p_{corr} = 1.059 (see Figure 1b).

Independent-sample *t*-tests with the GROUP (design vs. non-design) as a between-subject factor were performed on TTCT-figural originality and TTCT-figural fluency. The resulting *p* values were FDR corrected. A significant effect on TTCT-figural originality was observed, t (69) = 3.129, p_{corr} = .005, *Cohen's d* = .743. The design group exhibited higher originality than the non-design group (see Figure 1c). However, there was no significant difference in TTCT-fluency between the two groups, t (69) = −.040, p_{corr} = .968 (see Figure 1d).

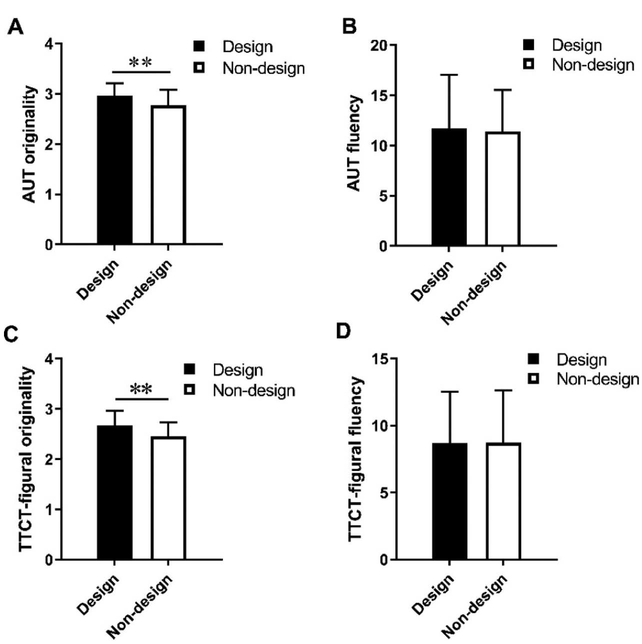

Figure 1. Group differences in AUT performance. (*A*) AUT originality. (*B*) AUT fluency. (*C*) TTCT-figural originality. (*D*) TTCT-figural fluency. Error bars indicate standard errors of the mean. *p < .05, **p < .01.

Group differences in product design performance

A series of independent-sample *t*-tests with GROUP (design vs. non-design) as a between-subject factor were performed on all nine indices (examples of a product design; see Figure 2). The resulting *p* values were FDR corrected. Significant effects on eight indices were observed (see Figure 3). For appearance novelty, t (69) = 2.475, p_{corr} = .019, *Cohen's d* = .587; for esthetics, t (69) = 5.856, p_{corr} < .001, *Cohen's d* = 1.388; for elaboration, t (69) = 3.942, p_{corr} < .001, *Cohen's d* = .935; for concept novelty, t (69) = 2.602, p_{corr} = .011, *Cohen's d* = .617; for imagination, t (69) = 2.204, p_{corr} = .034, *Cohen's d* = .523; for likability, t (69) = 5.235, p_{corr} < .001, *Cohen's d* = 1.242; and for overall evaluation, t (69) = 2.961, p_{corr} = 006, *Cohen's d* = .703. These results revealed that the design group displayed better performance than the non-design group on all seven indicators of product design. Interestingly, for product functional fluency, the non-design group exhibited higher functional fluency than the design group, t (69) = −3.991, p_{corr} < .001, *Cohen's d* = −.944. Concerning functional novelty, no difference was observed between the two groups, t (69) = −.001, p_{corr} = .999. Thus, the design group had better product design performance than the non-design group except for functional fluency and functional novelty.

Further, the composite indices were calculated to distinguish product originality from product amenity and to explore their respective impact on comprehensive evaluation. First, in order to eliminate the influence of functional fluency on functional novelty, functional originality percentage was calculated (functional originality percentage = functional novelty/functional fluency). Then, as a key dimension of design creativity evaluation, originality is multifaceted. In other words, there are many elements underpinning it which include functional novelty, appearance novelty, and even abstract ones such as imagination and concept novelty. Accordingly, indices that are more conceptually related to originality or novelty, including functional originality percentage, appearance novelty, imagination and concept novelty were calculated as the "originality" aspect (product originality = functional originality percentage + appearance novelty + imagination + concept novelty). This index providing a total score for product novelty. "Amenity" is another important dimension of design evaluation and seems to have an emotional or hedonic tone when compared to judgment of originality (Christensen & Ball, 2016). It not only depends on the object itself (e.g. symmetry, complexity and contrast), but also profiles of the perceivers such as personal taste and interests on the object. So, indices that are more

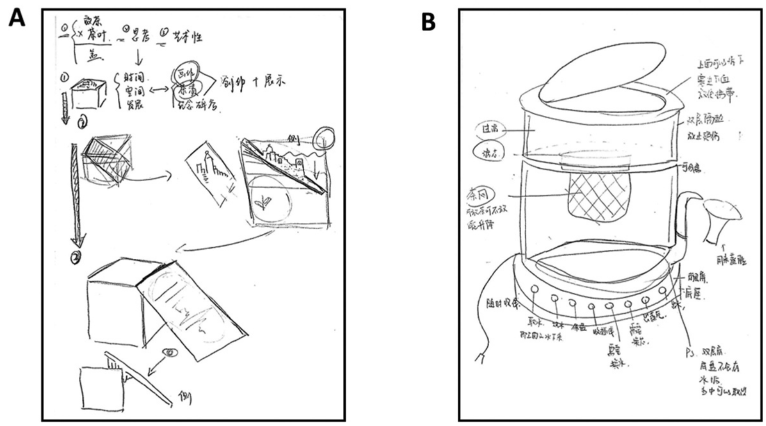

Figure 2. Examples of product design drafted by the design group *(A)* and the non-design group *(B)*. (A) Interpretation: Functionally speaking, in addition to holding water and tea, a tea-filtering function was added (When placed obliquely, the small holes on the lid could filter water and stop tea leaves from passing through). In terms of artistic display, the lid was designed as the "Monument Valley" Building. When slanted into the teapot, the horizontal surface rose and fell to reveal different scenes. Additionally, the teapot was made of ceramics. The reverse side of the lid was not glazed so tea stain could form natural paintings that could be displayed when the lid was revealed. Philosophically speaking, the design made people think about time, space and the development of things. For example, the buildings emerged as water went down in the pot. This could remind people of the passage of time and encourage them to form a clearer view of themselves and the world. Scores: Functional novelty = 3.67, Functional usefulness = 4.33, Functional fluency = 2.00, Appearance novelty = 4.67, Esthetics=4.33, Elaboration = 4.00, Concept novelty = 5.00, Imagination = 5.00, Likability=5.00, Overall evaluation = 4.33. (B) Interpretation: This Teapot consisted of the upper, middle, and lower parts. The main body was double glass design, which could insulate heat and prevent scald. First, the upper part could be separated from the pot to filter tap water. After passing through the filter, pure water would go to the middle part. Second, the lower part could be heated and there was a special net to hold tealeaves in the middle part. Tea water could come out of the spout automatically with the press of a button. When replaced by a larger disc spout, the teapot could be used as a steam mask. The middle part had a double bottom to prevent scaling. Third, the buttons in the lower part-controlled water intake, water boiling, heat preservation, wire insertion, induction water exchange, induction filter exchange, steam outlet, and water outlet. In sum, this teapot combined all the functions of teapots in the market. Scores: Functional novelty = 3.33, Functional usefulness = 4.0, Functional fluency = 4.0, Appearance novelty = 1.33, Esthetics=1.33, Elaboration = 2.33, Concept novelty = 2.33, Imagination = 2.33, Likability=2.0, Overall evaluation = 2.67.

conceptually related to appreciation of beauty, including esthetics, elaboration and likability, were calculated as the "amenity" aspect (product amenity = esthetics + elaboration + likability). This index yielding a total score for product agreeableness. Independent-sample *t*-tests with GROUP (design vs. non-design) as a between-subject factor were performed on these three composite indices. The resulting *p* values were FDR corrected. Significant effects on three indicators were observed (see Figure 3). For functional originality percentage, $t\ (69) = 4.026$, $p_{corr} < .001$, *Cohen's* $d = .995$; for product originality, $t\ (69) = 3.047$, $p_{corr} = .003$, *Cohen's* $d = .723$; and for product amenity, $t\ (69) = 5.816$, $p_{corr} < .001$, *Cohen's* $d = 1.380$.

Group differences in book cover design performance

A series of independent-sample *t*-tests with the GROUP (design vs. non-design) as a between-subject factor were performed on all nine indices (for examples of book cover design, see Figure 4). The resulting *p* values were FDR corrected. Significant effects on seven indicators were observed (see Figure 5a): for content originality, $t\ (69) = 7.039$, $p_{corr} < .001$, *Cohen's* $d = 1.669$; for drawing novelty, $t\ (69) = 8.823$, $p_{corr} < .001$, *Cohen's* $d = 2.096$; for esthetics, $t\ (69) = 8.461$, $p_{corr} < .001$, *Cohen's* $d = 2.006$; for elaboration, $t\ (69) = 8.188$, $p_{corr} < .001$, *Cohen's* $d = 1.949$; for imagination, $t\ (69) = 5.336$, $p_{corr} < .001$, *Cohen's* $d = 1.270$; for likability, $t\ (69) = 7.680$, $p_{corr} < .001$, *Cohen's* $d = 1.822$; and for overall evaluation, $t\ (69) = 8.242$, $p_{corr} < .001$, *Cohen's* $d = 1.956$. For all these seven indicators of product design, higher scores were found in the design group than the non-design group, no significant differences were observed in content appropriateness ($t\ (69) = -.431$, $p_{corr} = .668$) and content fluency ($t\ (69) = -.373$, $p_{corr} = .710$). Thus, the book cover design performance of the design group was better than that of the non-design group except for content novelty and content usefulness.

Similar to product design task, to distinguish originality from amenity and explore their respective impacts on the comprehensive evaluation, three composite indices were calculated: content originality percentage = content novelty/content fluency; book cover originality = content originality percentage + drawing novelty + imagination; and book cover amenity = esthetics + elaboration +

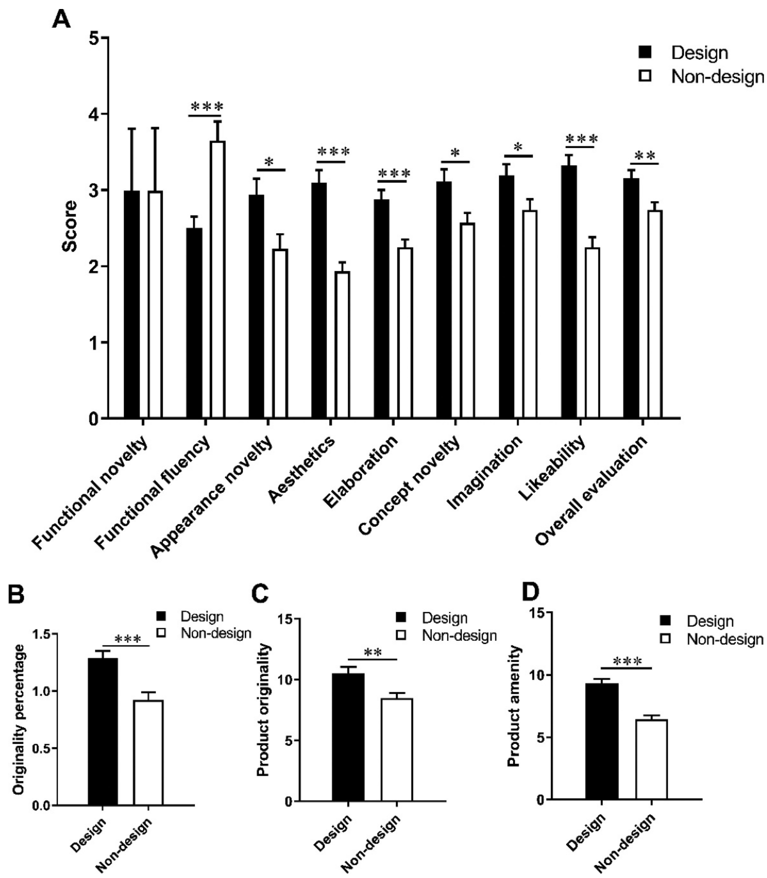

Figure 3. Group differences in product design performance. (*A*) Group differences on nine indicators: Functional novelty, Functional fluency, Appearance novelty, Esthetics, Elaboration, Concept novelty, Imagination, Likability, and Overall evaluation. (*B*) Originality percentage. (*C*) Product originality. (*D*) Product amenity. Error bars indicate standard errors of the mean. *$p < .05$, **$p < .01$, ***$p < .001$.

likability. Independent-sample *t*-tests with the GROUP (design vs. non-design) as a between-subject factor were performed on the composite indices. The resulting *p* values were FDR corrected. Significant effects on all three indicators were observed: for originality percentage (see Figure 5b), t (69) = 5.287, $p_{corr} < .001$, *Cohen's d* = 1.259; for book cover originality (see Figure 5c), t (69) = 8.443, $p_{corr} < .001$, *Cohen's d* = 2.006; and for book cover amenity (see Figure 5d), t (69) = 8.804, $p_{corr} < .001$, *Cohen's d* = 2.086.

The predictive effect of domain-general creativity on product design performance

To investigate the relations among design training, domain-general creativity (AUT originality and TTCT-figural originality) and domain-specific creativity (product originality, amenity and overall performance), linear regression analyses were performed using SPSS (version 20.0). Within the model (see Figure 6), the influences of GROUP (*design* = 1, *non-design* = 0) on AUT originality ($\beta = .353$, $t = 3.135$, $p = .003$) and TTCT-figural originality ($\beta = .353$, $t = 3.129$, $p = .003$) were significant; GROUP and TTCT-figural originality were positively associated with product originality ($\beta = .253$, $t = 2.096$, $p = .040$; $\beta = .317$, $t = 2.592$, $p = .012$); GROUP and TTCT-figural originality were positively associated with product amenity ($\beta = .474$, $t = 4.545$, $p < .001$; $\beta = .292$, $t = 2.766$, $p = .007$); and product originality and amenity were positively related with product overall evaluation ($\beta = .367$, $t = 4.406$, $p < .001$; $\beta = .675$, $t = 6.999$, $p < .001$). These results indicated that product originality and amenity mediated the link between GROUP (design vs. non-design) and product overall performance. Moreover, the model also revealed that GROUP first influenced TTCT-figural originality, which then influenced product originality and amenity, which consequently influenced product overall evaluation. That is, TTCT-figural originality and product originality played sequential mediation roles between GROUP and product overall evaluation.

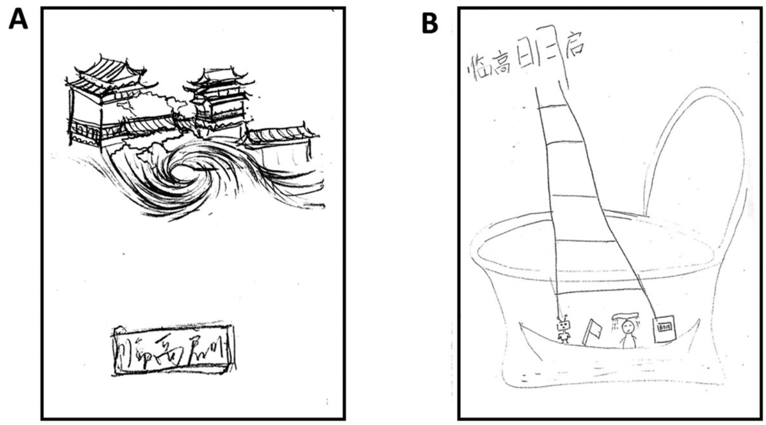

Figure 4. Examples of book cover designed by the expert group *(A)* and the novice group (*B*). (A) Interpretation: The novel was about time traveling, and the book introduction could create a sense of magic and fantasy, so I combined the elements of "wormhole" and "Ming dynasty" in the cover. My original idea was to draw some Ming Dynasty buildings in the middle, and then twist, deform or rotate them to create a "wormhole" look. This design was more in line with the fantasy genre. However, since time was limited, I gave up the original idea and separated the "wormhole" and "Ming Dynasty." I also intended to create a seal effect using an ancient font for the title "Back to the Ming Dynasty" and the author's name to represent the historical times. Scores: Content novelty = 3.40, Content appropriateness = 3.67, Content fluency = 3.00, Drawing novelty = 3.40, Esthetics=3.80, Elaboration = 4.00, Imagination = 3.40, Likability=3.20, Overall evaluation = 3.40. (B) Interpretation: Since the wormhole that allowed people to time travel to the Ming Dynasty was actually found in the toilet, so the toilet was painted. People with different ambitions went back to the Ming Dynasty together in a small boat, so I drew symbols to represent these people: Robot symbolized technology, ax symbolized industry, emperor symbolized preventing chaos, and book symbolized modern knowledge. Furthermore, because these people failed in their respective realities, they all wished to realize their dreams through the ladder back to the Ming Dynasty. Also, the ladder was getting narrower because very few people could succeed. Scores: Content novelty = 2.40, Content appropriateness = 2.67, Content fluency = 2.50, Drawing novelty = 2.00, Esthetics=1.33, Elaboration = 1.60, Imagination = 2.60, Likability=1.40, Overall evaluation = 2.00.

The predictive effect of domain-general creativity on book cover design performance

To investigate the relations among design training, domain-general creativity (AUT originality and TTCT-figural originality) and domain-specific creativity (book cover originality, amenity and overall performance), linear regression analyses were performed using SPSS (version 20.0). Within the model (see Figure 7), the influences of GROUP (*design* = 1, *non-design* = 0) on AUT originality (β = .353, t = 3.135, p = .003) and TTCT-figural originality (β = .353, t = 3.129, p = .003) were significant; GROUP and TTCT-figural originality were positively associated with book cover originality (β = .595, t = 6.751, p < .001; β = .208, t = 2.327, p = .023); GROUP was positively associated with book cover amenity (β = .666, t = 7.362, p < .001); and book cover originality and amenity were positively related with book cover overall evaluation (β = .332, t = 4.464, p < .001; β = .691, t = 9.541, p < .001). These results indicated that book cover originality and amenity mediated the link between GROUP (design vs. non-design) and task performance. This finding illustrated the stability of the mediation model found in product design task. Moreover, the model also revealed that GROUP first influenced TTCT-figural originality, which then influenced book cover originality, which consequently influenced book cover overall evaluation. That is, TTCT-figural originality and book cover originality played sequential mediation roles between GROUP and book cover overall evaluation. This finding also illustrated the partial stability of the sequential mediation model found in product design task.

Discussion

This study explored the differences in domain-general and domain-specific creativity between design experts and novices and tested the mediating effect of domain-general creativity in the relationship between GROUP (design vs. non-design) and domain-specific creativity. The results revealed that (1) design training students exhibited better domain-general divergent thinking skills (both verbal and visual) than non-training students; (2) design training students exhibited better domain-specific design creativity than non-training students, both in product task and book cover task; (3) design training enhanced design creativity through the "originality" pathway and "amenity" pathway. Moreover, (4) GROUP (design vs. non-design) first influenced visual divergent thinking and then influenced design originality and amenity, which in turn influenced design overall evaluation.

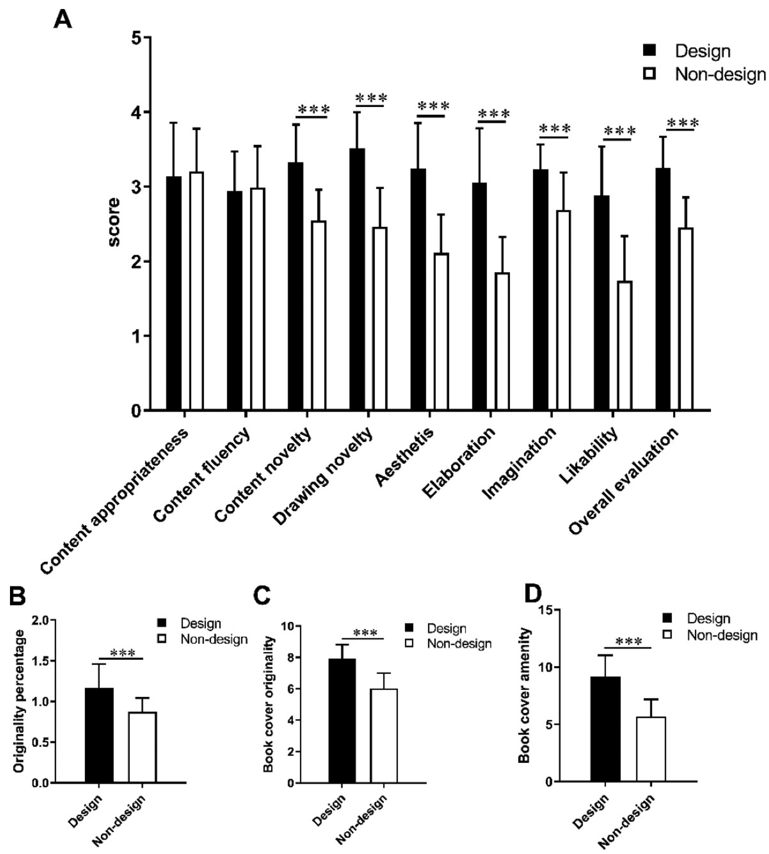

Figure 5. Group differences in book cover design performance. (*A*) Group differences on nine indicators: Content appropriateness, Content fluency, Content novelty, Drawing novelty, Esthetics, Elaboration, Imagination, Likability, and Overall evaluation. (*B*) Originality percentage. (*C*) Book cover originality. (*D*) Book cover amenity. Error bars indicate standard errors of the mean. *p < .05, **p < .01, ***p < .001.

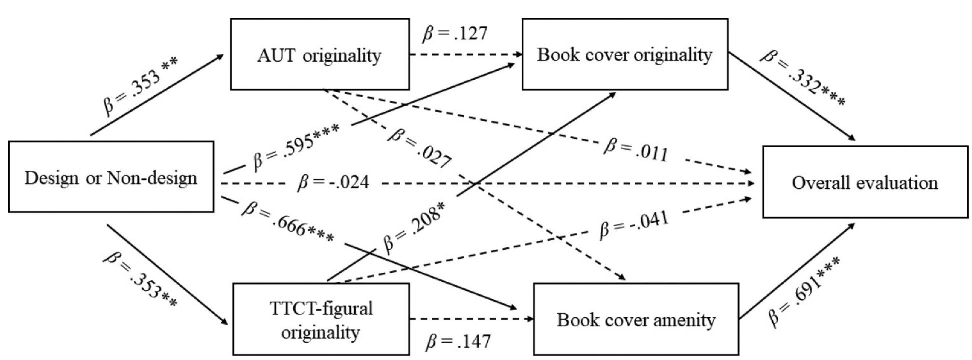

Figure 6. Regression analysis of the effects of group (design or non-design) on product task performance via AUT originality and TTCT-figural originality. Dashed lines indicate non-significant effects. *p < .05, **p < .01, ***p < .001.

Partially consistent with previous findings (Edl et al., 2014), our results revealed that design experts showed significantly better verbal and visual divergent thinking skills than novices. The controlled-attention theory of creativity suggests that creative ideas arise from the ability to exert top-down control over attention and cognition (Gilhooly, Fioratou, Anthony, & Wynn, 2007). Previous research demonstrated that better involvement in the artistic (versus information technology domain) professions was associated with better common executive function (EF), enhanced mental set-shifting abilities (Zabelina, Friedman, & Andrews-Hanna, 2019), and higher irrelevant interference inhibition (Edl et al., 2014). People in the artistic professions may be able to actively regulate their thoughts and behaviors by guiding their cognition in the most

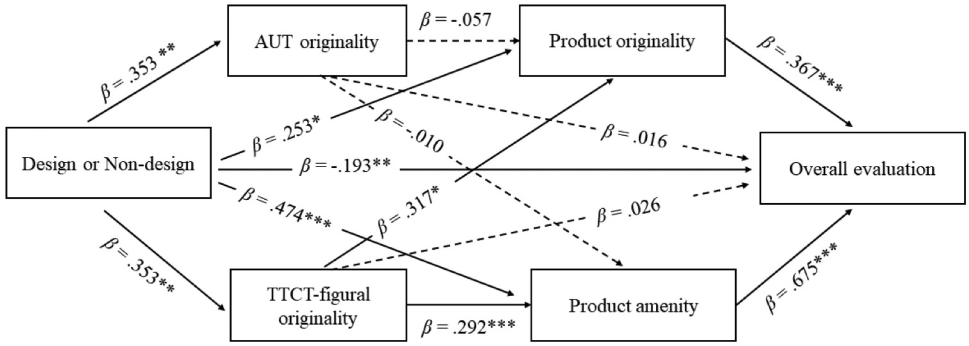

Figure 7. Regression analysis of the effects of group (design or non-design) on book cover task performance via AUT originality and TTCT-figural originality. Dashed lines indicate non-significant effects. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

appropriate ways, as reflected in their better overall EF, flexibly shift between goals and ideas, and better shifting-specific abilities. As a consequence, they may be better at both verbal and visual divergent thinking tasks.

Results found that design experts produced a significantly better product and book-cover design performance than novices, not only in “originality,” but also “amenity.” In addition, the post-experimental tests showed no significant difference between the groups in depletion, enjoyment, task engagement, and task difficulty during product design task ($t\ (68) = -1.51$, $p = .136$; $t\ (68) = -.92$, $p = .361$; $t\ (68) = -.42$, $p = .678$; $t\ (68) = -.91$, $p = .365$) or book cover design task ($t\ (68) = -1.67$, $p = .100$; $t\ (68) = .06$, $p = .950$; $t\ (68) = .59$, $p = .561$; $t\ (68) = -1.19$, $p = .237$). Accordingly, the results might indicate that design and non-design majoring students were equally engaged in the tasks. To our knowledge, this may be the first study to examine expert-novice differences in design task performance through a system evaluation (multiple dimensions and two aspects). According to the Componential Theory of Creativity proposed by Amabile (1996), creativity is produced by the interactions among domain-relevant skills, creativity-relevant processes, and task motivation. Building on Gestalt psychology, researchers assume that creative problem-solving involves the reorganization of existing knowledge to identify new solutions. One of the key reasons why experts and novices differ in design task performance is that novices are lacking in domain and procedural knowledge, which can be used to construct more abstract schemas (Ozkan & Dogan, 2013; Popovic, 2004). A second difference relates to differences in drawing skills, which lead the better performance in the design “amenity” (e.g., esthetics, elaboration, and likability indicators). These results provide evidence for the domain-specific theory of creativity, which assumes that creativity in different domains involves diverse knowledge and creative thinking skills, dispositions, or tendencies (Baer, 2010).

Moreover, results found that GROUP (design vs. non-design) first influenced TTCT-figural originality and then influenced design originality, which in turn influenced design overall evaluation, this pathway were stable across the product and book cover design tasks. Design training may enhance general cognitive abilities, such as cognitive flexibility, visual imagination, and free-association, which could improve both domain-general and domain-specific creativity. Another explanation might be that design training improved divergent thinking directly, which further benefited design creativity. Accordingly, this might support the domain-general theory of creativity, assuming that creative performance in various areas could be enhanced by training these basic creative processes (such as divergent thinking) (Plucker, 1998). Based on these results, a pioneering framework was established to understand the manner in which design training improves design performance through visual divergent thinking.

We noted the issue of why ideational originality, but not ideational fluency was a predictor of creative thinking in the product and book cover design task. According to the dual-process model of creativity (Finke, Ward, & Smith, 1992), creative thinking includes two processes: concept generation and concept evaluation. Design thinking training also includes two processes: it not only encourages students to think freely about more ideas but it also encourages them to carry on high-quality creative thinking. The higher originality idea relies on a dynamic interplay between the processes of concept evaluation and concept generation. Unlike untrained students, design students could utilize idea evaluation processes to help them filter out ideas with low novelty.

Our results also revealed that the domain-specific design "originality" aspect was more strongly predicted by the scores on the figural rather than verbal stimuli in domain-general creative thinking. A possible explanation of this finding concerns the "visual language" used in design cognition. According to educators of art, architecture, and design, design cognition relies on a formal visual language, formalized and clarified by basic principles of design. This formal visual language can help individuals attain a degree of originality in the cognitive, affective, and psychomotor domains of creativity (Wallschlaeger & Busic-Snyder, 1992). In Demirkan and Hasirci's (2009) study, basic principles of design – design elements and their assembly – were also considered as the hidden dimensions of creativity. The design elements were defined as the characteristics of design important in creating a pattern, and these elements can be listed as shape/form, color, space, line value, and texture. Furthermore, the way the design elements came together was the assembly of design elements, listed as harmony, emphasis, rhythm, unity, variety, repetition, and balance (Demirkan & Afacan, 2012). The visual language that designers use can be considered the sources that contribute in distinguishing their levels of expertise (Popovic, 2004).

In sum, "Creativity" is widely regarded as an essential element in design thinking, However, designers themselves often emphasize the role of "intuition" in the generation of solutions. Creative design is often characterized by the occurrence of a significant event, adding an element of mystery to the process of creativity. The model in this study suggested that "originality" and "amenity" were both crucial for good design, and training of visual divergent thinking skills may be a pathway for improving design creativity. We hoped this study of creative events in design may illuminate the mysterious aspects of design and have implications for design education in the future.

A limitation of this study concerns the recruitment of design majoring students as the expert group. Since it is commonly accepted that experts are supposed to be engaged in a specific domain for at least 10 years, future studies may recruit experts with at least 10 years of design experience as the expert group, or compare the new design students to sophomore design students, to further reveal the expert-novice differences in domain-general creativity and domain-specific creativity. Second, given the complexity of design problem-solving which also involves various stages and processes (Goel, 1995), the 15-minute task duration in this study might be a little too short. To fully explore design cognition, a longer task duration should be considered in future studies.

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Disclosure statement

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