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Online Creativity Training: Examining the Effectiveness of a Comprehensive Training Approach

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Abstract
In today's rapidly changing and technology-driven world, the ability to think creatively is essential for individuals and organizations. To date, technology-based training has become a new trend for learning and training in the 21st century; however, little empirical research has been conducted to enhance creativity through online training. In the current study, we developed and examined an online creativity training program, which employed a comprehensive training approach and consisted of twenty self-instructional exercises delivered throughout five weeks. The effectiveness of the training was examined by means of a pre-posttest between-subjects design with two control groups (i.e., a creativity-unrelated online memory training; no-training). Four well-validated tasks tapping onto divergent and convergent thinking were used to measure participants' creativity. Upon following the online creativity training, participants' performance tended to significantly improve on several indices of divergent thinking (e.g., fluency, flexibility, originality). For the two control groups, no difference in divergent thinking was observed between the pretest and posttest. Besides, no training effects were observed on convergent thinking. The current findings increase our understanding of enhancing creativity through online training and provide a new comprehensive training approach, which may contribute to the enhancement of creativity in educational and organizational settings.

Keywords Creativity · Creativity training · Online training · Comprehensive training approach · Divergent thinking

Creativity plays a vital role in our lives (Amabile, 1996; Sternberg & Lubart, 1995). It is considered as one of the most important resources for economic success (Florida, 2002; Kaufman & Beghetto, 2009; OECD, 2004). Creative thinking has become a desirable skill in employees to grasp the opportunities, speed up the innovation cycle, and succeed in the workforce (Adobe, 2012; Robinson, 2014). It is also important for problem solving in

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everyday life, especially when conventional solutions fail and novel solutions are required (Hennessey & Amabile, 2010). Moreover, creativity helps to promote well-being and it enhances our mental and emotional health (Conner et al., 2018; Csikszentmihalyi, 1996). Given the importance of creativity in societies and individuals, it is desirable that our creative ability can be further developed.

In the scientific literature, creativity has been defined in many different ways. For example, Sternberg and Lubart (1999, p. 3) defined creativity as "the ability to produce work that is both novel (i.e., original, unexpected) and appropriate (i.e., useful, adaptive concerning task constraints)". Plucker et al., (2004, p. 90) defined creativity as "the interaction among aptitude, process, and environment by which an individual or group produces a perceptible product that is both novel and useful as defined within a social context". Though slightly different, most research agrees that creativity is the capacity to generate ideas or solutions that are original and useful (Corazza, 2016; Runco & Jaeger, 2012). In the current study, we refer to creativity as a creative potential, which is not about the actual creative achievement that a person has achieved (Barbot et al., 2015), but a latent ability to generate creative work.

While previous studies have shown that creativity can be enhanced through training (for reviews see Ma, 2006; Scott et al., 2004a, 2004b), only limited empirical research has examined the effectiveness of enhancing creativity through online training (see Scott et al., 2004a). The current study developed and examined a five-week online creativity-training program, which focused mainly on general creative thinking skills, under the presumption that these skills can be used for a wide range of tasks. In the remaining part of the introduction we first focus on creativity and its components, creativity training framework, and then we provide an overview of the existing literature about online creativity training.

Creative process and factors affecting creativity

How do creative ideas emerge? According to the creative cognition approach (Ward et al., 1999), the creative process shares the same basic cognitive processes that underlie non-creative endeavours. During creative thinking, certain cognitive processes are recruited and combined to generate creative ideas (Smith et al., 2006; Ward et al., 1999), for instance, by flexible use of concepts (e.g., use a shoe as a flower pot; Nijstad et al., 2010) or by associating remote concepts (e.g., a self-driving suitcase is produced by combining "remote control" and "luggage"; Mednick, 1962; Ward et al., 1999). A cognitive approach not only helps to demystify creativity but also implies that creative ability can be enhanced, just as some other cognitive abilities (Finke et al., 1992; Ward, 2001).

Creativity does not rely on cognitive processing alone. Rather, the creative process can be influenced by personal and contextual factors. Many researchers have agreed on the multifaceted nature of creativity (Lubart et al., 2013; Rhodes, 1961; Runco, 2004; Snow, 1994; Sternberg & Lubart, 1995). Rhodes (1961) proposed the 4Ps' theory, which suggests that a person's creativity comprised four aspects: *Person, Process, Press,* and *Product*. *Person* refers to characteristics or traits that are of creative personality such as tolerance of ambiguity (e.g., Wu et al., 2019). *Process* refers to the cognitive processes that underlie creative thinking such as flexible thinking and remote associations (Benedek et al., 2012; Mednick, 1962). *Press* refers to environmental influences, such as organizational (e.g., Shalley et al., 2004) or educational settings (Besançon et al., 2015; Thomas & Berk, 1981). Finally, *Product* refers to the creative outcomes that result from the creative process,

including either tangible objects (e.g., an energy-saving car) or abstract products (e.g., a poem) (Simonton, 2010). Usually a creative product is generated by a person using cognitive processes within a specific context (press). This suggests that when aiming to train creativity, it may be beneficial to take the person, process, press, and product aspects into account.

5-I training framework

The 5-I training framework was employed to develop the creativity training of the current study. It centres around *Inclination, Ideation, Interaction, Identification*, and *Inspiration*. *Inclination* focuses on the *person* aspect (Gu et al., 2019). It aims to develop creativity-relevant personality traits. For example, participants' tolerance of ambiguity was trained by exposure to ambiguous figures, which increased participants' tolerance of ambiguous situations. *Ideation* focuses on the *process* aspect and aims to stimulate the cognitive processes underlying creative thinking. For example, in the current training participants' associative ability was trained by the random connection exercise, which asked participants to design new types of sun creams by associating it with characteristics of an unrelated object (e.g., ballpoint pen) (Ritter & Mostert, 2017). *Interaction* focuses on the *press* aspect, which refers to an environment or climate that is conducive to creativity. In the current training, a free and non-judgmental environment was created. *Identification* focuses on the *product* aspect. It aims to train participants' abilities in identifying creative ideas. Hence, we designed several training exercises involving the process of not only generating creative ideas but also evaluating and selecting ideas that fit the task constraints. *Inspiration* aims to evoke an intrinsic motivation to be creative, which is considered as a necessary resource supporting creativity (Oleynick et al., 2014; Thrash et al., 2010). Although there are studies that have suggested a positive relationship between creativity and inspiration (e.g., Oleynick et al., 2014; Thrash et al., 2010), few studies have included inspiration as a training component. In the current training, ten exercises were incorporated, each focusing on one or several components of the 5-I training framework. An overview of the exercises is provided in the Appendix 1, and a detailed description of the exercises is provided in the Method section.

Online training

Technology-based training, and online training in particular, has become a new trend for learning and training in 21st century (Lubart, 2005; Paradise, 2007). Compared with traditional, non-online training, online training has several advantages. For example, online training increases training accessibility and flexibility (Evans & Haase, 2001). Also, online training is cost efficient — it neither requires a trainer nor a physical location (Evans & Haase, 2001). Additionally, online training is more learner-centered and increases trainees' autonomy (e.g., they can have control over the training speed) (Bartley & Golek, 2004).

Nevertheless, a review on the effectiveness of creativity trainings conducted by Scott et al., (2004a) revealed that most of the training programs employed a traditional, in-person training approach. Findings from the traditional training suggest that effective creativity training programs should provide cognitive skills or strategies for creative thinking and allow practice on these skills (Scott et al., 2004a). For example,

Bruton (2011) combined creative problem solving strategies and grammatical design in an innovation and creativity course, and the results showed that an interdisciplinary course was effective in fostering creative ideas among university design students. Previous literature has suggested that, online/computer-based training, though limited in empirical evidence, is also effective in fostering creativity (Benedek et al., 2006; Chang, 2013; Scott et al., 2004a). For example, Benedek et al. (2006) showed that participants who took part in nine sessions of a computer-based divergent thinking training showed enhanced performance in fluency and originality. Chang (2013) trained students' technological creativity with an online creative problem solving program; however, students' creative performance was measured using a technological creativity test in the pretest but a creative thinking test in the posttest.

So far, little research has been done to examine the effectiveness of online creativity training regardless of its effectiveness and advantage in delivering training. Besides, most of the existing research merely employed a cognitive approach (e.g., Benedek et al., 2006; Cassidy, 2011) while ignoring other factors affecting creativity. As noted above, development of creativity is ideally a combination of multiple personal and environmental factors. Taken together, previous research has provided some preliminary evidence concerning the effectiveness of online creativity training and further research is needed.

The current study

In the current study, the effectiveness of an online creativity training program was examined using a pre-posttest between-subjects design. The training techniques were developed based on the 5-I training framework, that is, a comprehensive training approach. Participants practiced the training exercises in their daily life settings in a self-instructional manner over a period of five weeks, and no trainer was involved. In this way, participants could regulate the pace of the training instructions. Moreover, there was a practice stage after the learning stage of each technique, which facilitated participants to actively engage in the online training. Previous studies have suggested that active learning is an effective strategy to increase learners' motivation and engagement and to develop higher order thinking skills (Davis et al., 2018; Gu et al., 2022a, 2022b).

Two control groups were employed, one group received an online memory training, and the other group did not receive any training exercises. The training exercises applied were different from the creativity measures consisted of four creativity tasks (i.e., Alternative Uses Task, Remote Associate Test, Insight problem, and Real-life problem), aiming to measure two main types of creative thinking: Divergent thinking and convergent thinking. Divergent thinking refers to the ability to generate many possible solutions by searching in different directions (Guilford, 1967) while convergent thinking refers to the ability to select a single "correct" answer that best fits a given problem (Cropley, 2006; Simonton, 2003). A detailed description of the creativity measures is provided in the Method section.

We hypothesized that the current comprehensive online creativity training significantly enhances participants' creative performance from pretest to posttest, whereas for the two control groups no difference in performance is observed. Moreover, we hypothesized that creative performance on the posttest is higher for the creativity training group as compared to the two control groups.

Method

Participants

Before data collection, a priori power analysis was conducted to determine the sample size required for the current study. Given that in the area of the current study no previous studies could be referred to calculate the sample size, we used a medium effect size of 0.5 (Cohen' d), which Cohen (1988, p.25) described as "an effect likely to be visible to the naked eye of a careful observer". The power analysis revealed that a minimum of 129 participants is required to obtain a statistical power of 0.80 for a 2×3 repeated measures design with alpha = 0.05, a medium effect size (Cohen' d) = 0.5, and degrees of freedom = 126 (PANGEA; Winer et al., 1991). We planned to recruit slightly more participants to compensate for dropouts during the training. Participants were recruited from a university research participation system (SONA) and via flyers on the campus. In total, 136 participants signed up (19 males, 117 females), with an average age of 20.7 ($SD = 2.83$). Participants were rewarded with six course credits or €60 for their participation. The current study was approved by the Ethics Committee of the Faculty (approval code: ECSW-2018-106). The method, materials, and data analysis plan were preregistered on the Open Science Framework (see https://osf.io/vje8a/?view_only=0c94fa13e71e42e19a4f9c33fb9e8f72).

Following the pre-registered inclusion criteria, participants who did not regularly attend the creativity training or memory training program (less than 80% of all training days, that is, less than 16 days), and those who didn't take the exercises seriously (e.g., very short time spent on performing the tasks), were excluded from data analyses. In total, ten participants had to be excluded from data analyses: five participants spent less than ten minutes or more than two hours on the pretest or posttest, two participants in the creativity training group performed the exercises less than 16 days and/or practiced an exercise shorter than five minutes, one participant did not perform the posttest, and two participants dropped out. The data analyses included the remaining 126 participants (18 males, 108 females), which somewhat met the minimum sample size. Chi-square revealed no gender difference between groups, $X^2(1) = 5.27$, $p = 0.072$.

Procedure

After signing up, participants were randomly assigned to one of the three training groups depending on the order they signed up. Each participant received a subject code as its identity in the study. All data were collected using online survey platform Qualtrics.

Pretest. All participants took part in the creativity pretest. Participants performed the AUT, RAT, insight problem and real-life problem (see Measures below). Thereafter, they provided information regarding their age, gender and study. In total, the pretest took about 20 min.

Online training. The training was actualized as a computer training using Qualtrics. In total, the online training lasted for five weeks. Each week, from Monday to Thursday, participants in the creativity training and the memory training group performed a daily exercise, which took about 10–15 min and participants could work on it with their laptop, mobile phone, or tablet. In the morning, participants received an email with a link to the exercise, which they could open with their subject code

and perform anytime during the day. When practicing an exercise, the purpose of the exercise was first briefly introduced. Afterwards, participants were guided through the exercise by following instructions on the screen. Participants could thereafter enter their responses into an empty box that was also displayed on the screen. After completion of an exercise, example solutions to solve the problem were provided to participants. In general, there was no time limit to finish an exercise, and participants could close the webpage after completing an exercise. For example, in the exercise "Finding differences", first, the exercise was briefly introduced and participants were shown pictures of the five items (a book, skates, a tricycle, a sledge and a train). They were asked to think about which item differs from the other four items. On the response page, all five items were listed again, including an answer box per item, and participants could indicate their answer(s) by ticking the answer box(es) of the item(s) in question. In an additional answer box, participants could provide an explanation for the choice made. Finally, participants were provided with the solutions, that is, for each item a reason can be found why it differs from the other items (see Exercise 2). Participants in the no-training group received no exercise during the training session.

Posttest. In the posttest, participants performed a different version of the four creativity tasks. In total, the posttest took about 15 min.

Before and after the training, participants reported a couple of additional questions (e.g., participants' well-being) that were not examined in the current study and thereby will not be discussed below.

Creativity training

Ten creativity training exercises were developed, each focusing on at least one component of the 5-I training framework. Each training exercise had two versions, which used the same training procedure but differed in materials. The twenty creativity training exercises were spreaded over five weeks.

Exercise 1: inspirational inventions

In this exercise, participants were exposed to a couple of inventions, such as a ketchup gun and a Bluetooth-controlled suitcase. Thereafter, participants had to generate ideas for inventions themselves. This exercise aimed to increase participants' creative inspiration, which can lead to a motivational state conducive to creative thinking (Oleynick et al., 2014; Thrash et al., 2010).

Exercises 2: finding differences

This exercise aims to stimulate participants to look at a problem from different perspectives. Participants were presented with five items—a book, skates, a tricycle, a sledge and a train—and were asked to identify the item that differs from the other items (Meyer, 2011). Actually, each item can be considered different from the other four items. For example, a

book is the only item that cannot be used for transport, two skates are needed for skating, a tricycle is used by children only, a sledge is the only item used in the snow, and a train is the only item that needs electricity. Practicing to look at problems from different perspectives stimulates participants to flexibly change strategies to solve a problem and to come up with solutions from diverse domains (Garner, 2009; Thurston & Runco, 1999).

Exercises 3: schema violation

A schema-violation refers to a situation or event that violates expectancies or conventions (Gocłowska et al., 2014; Ritter et al., 2012). When faced schema violating situation (e.g., a snowman in dissert), individuals have to overcome the influence of stereotypic knowledge and think flexibly in order to organize and interpret the schema-inconsistent information. Earlier research has shown that experience of schema inconsistencies stimulates individuals to think outside conventional thinking and enables a greater flexibility to generate creative ideas that are further away from stereotypical ones (Gocłowska et al., 2014; Ritter et al., 2012). In this exercise, participants were encouraged to break their daily routine and solve issues in non-normative ways. For example, they could prepare a different breakfast or take a different route to the university. At the end of the day, participants listed all "breaking the routine" activities that they had performed during the day.

Exercise 4: ambiguous figures

In this exercise, participants were presented with a list of ambiguous figures and were asked to describe what they see in the figures. Each ambiguous figure can be interpreted in more than one way. To recognize objects in these ambiguous figures, participants need to tolerate the ambiguity and view the figures from different angles. This exercise aimed to foster participants' tolerance of ambiguity and uncertainty in that creative ideas are often needed in situations that are complex and ambiguous (Zenasni et al., 2008). It has been suggested that people who have a higher level of tolerance of ambiguity are more comfortable with ambiguous situations and more likely to search for many novel solutions (Stoycheva, 2010; Wu et al., 2019).

Exercise 5: stroop task

In the Stroop task, participants were presented with a series of coloured words (e.g., red) printed in incongruent colours (e.g., green), and they had to respond to the colour of the word (e.g., green) (Stroop, 1935). To respond to the colour of the word correctly, participants needed to focus their attention on the ink colour of a word and inhibit the interference from its meaning, which requires greater involvement of cognitive control flexibility (Edl et al., 2014; Zabelina & Robinson, 2010). Previous research assumed that cognitive control flexibility is a characteristic of highly creative individuals, who exhibit a higher capacity in

avoiding task-irrelevant information and flexibly switching their attention to serve the task goals (Zabelina & Robinson, 2010).

Exercise 6: incomplete figure

In this exercise, participants were given a shape (e.g., a partial triangle) and asked to complete a drawing (TTCT; Torrance, 1966). In the drawing exercise, participants were free to draw whatever they imagined, add details and variations to the drawing, and express their thoughts and feelings in different ways. This task was hypothesized to help develop individuals' creative imagination and expression (Kim et al., 2016; Linqvist, 2003).

Exercise 7: constrained problem

This exercise asked participants to solve a problem by overcoming its constraints (Skillicorn, 2013). For example, "How to stop bees getting inside through an open window?" To solve this problem, participants may come up with many possible solutions, but they had to select a few solutions (e.g., have a spider spinning a web on the window) that fit the task constraints (i.e., open window). The constrained problem was supposed to train participants' abilities in both generation and recognition of creative ideas (Cropley, 2006; Sternberg & Lubart, 1999).

Exercise 8: words association

This exercise required participants to build word chains by filling in five blanks (Benedek et al., 2012; Skillicorn, 2013). The rule was that the first word should associate with the cue word, and all subsequent words should relate to previous ones (e.g., "kid–(parents)–(holiday)–(beach)–(sand)–(sea)–fish". In this exercise, participants were encouraged to make multiple chains of such word associations, which required them to think fluently and flexibly to generate words associations. This exercise was assumed to enhance participants' associative thinking, a fundamental cognitive process underlying creativity (Benedek et al., 2012; Mednick, 1962). Previous studies have indicated that participants' performance in the word association task is predictive of their ability in divergent thinking (Benedek et al., 2012).

Exercise 9: SCAMPER

This exercise asked participants to improve a teaspoon by using the SCAMPER technique. SCAMPER consists of seven methods: substitute, combine, adapt, modify, put to another use, eliminate, and rearrange (Osborn, 1953). Participants were first familiarized with the seven methods, and then they solved problems using these methods. For example, "How to improve a teaspoon": using the method "adapt" (i.e., adjust part of the spoon), participants could design a spoon with curved handle, which can rest on the rim of a cup. This exercise

provided participants with directed strategies to generate ideas, and therefore facilitated participants' generation of creative products by adapting features of the teaspoon in different directions. This exercise was supposed to tap into creative skills such as extending concepts and flexible thinking (Gu et al., 2022a; Ozyaprak, 2016).

Exercise 10: random connection

The random connection technique facilitates the generation of solutions by making associations with unrelated objects (de Bono, 1992; Ritter & Mostert, 2017). For example, the problem "How to design a new sun cream", can be solved with this technique in three steps. First, participants had to think of a random object, such as a ballpoint pen. Second, participants were asked to list different characteristics of the ballpoint pen (e.g., rolling, writing and colour). Finally, participants were challenged to apply these characteristics to the sun cream such as using the characteristics "rolling" to design a sun cream with roll-on function. This exercise stimulated participants to generate ideas by building associations between random objects, which were thought to facilitate the associative process of creative thinking (Gu et al., 2022a; Ward et al., 1999).

Memory training

The training procedure and style of the memory training group were roughly identical to those of the creativity training group, except the training content. In the memory training, participants were trained to remember things (see examples in Appendix 2). For example, in one exercise participants were asked to remember a list of 15 words in one minute. In another exercise, participants were asked to memorize a list of 10 shapes for three minutes, after which they had to recall the 10 shapes according to the original sequence. In total, ten memory training exercises were developed, each consisting of two exercise versions. The memory training was taken place at the same time as the creativity training group.

Measures

In the current study, four creativity tasks were employed to measure participants' creative performance on divergent and convergent thinking. Two versions of each task were used and counterbalanced between the pretest and posttest as well as across participants. Besides, the creativity measures differed from the training exercises.

Divergent thinking

Alternative Uses Task (AUT). In the AUT participants had to generate as many different uses of a brick (version A) or a newspaper (version B) within three minutes (Guilford, 1967). The wording of the task instructions was as follows: "What can you do with a brick?" and "What can you do with a newspaper?", respectively. Two raters who were blind to training conditions scored the generated ideas. Prior to scoring, raters excluded participants' incomplete and unclear ideas. Participants' performance on the AUT was

measured on five indices of creativity: (a) Fluency, the total number of ideas generated by a participant. (b) Flexibility, the total number of different categories that a participant's ideas can be assigned to. Therefore, a pre-defined list of idea categories was used. (c) Creativity, how creative an idea was. Raters were briefly explained that highly creative ideas should both original and useful. (d) Originality, how original an idea was. (e) Usefulness, how useful an idea was. One rater scored 100% of participants' ideas on creativity, originality and usefulness, using a 5-point scale (ranging from 1 "not at all [dimension]" to 5 "very [dimension]"). The interrater reliability was obtained by having a second rater scoring a random selection of 30% of participants' ideas on creativity, originality and usefulness. The intraclass correlation coefficient analyses (two-way random, consistency) showed excellent interrater reliability on creativity (ICC = 0.94), originality (ICC = 0.93) and usefulness (ICC = 0.94). For each participant, a mean score of creativity, originality and usefulness was calculated across all his/her ideas.

Real-life problem. Participants had to think of as many solutions as possible for a real-life problem within three minutes (de Buisonjé et al., 2017; Zhu et al., 2017). For task version A, the problem statement was "How to encourage people to reduce food waste" and for task version B the problem statement was "How can we stimulate children to eat fruits and vegetables?" Participants' performance was measured using fluency, flexibility, creativity, originality and usefulness that followed the same criteria as those in the AUT. The intraclass coefficients were excellent on creativity (ICC = 0.90), originality (ICC = 0.90), and usefulness (ICC = 0.84).

Convergent thinking

RAT. The RAT asked participants to think of a fourth word that associates with each of the three words given (e.g., sick: seasick, homesick, stomachsick; Mednick, 1962). In the current study, each version of the RAT had six sets of three-word combinations, and participants were asked to solve them within 3 minutes. One rater counted the number of participants' correct responses.

Insight problem. In this study, two well-known insight tasks were used. In version A, the candle task (Duncker, 1945) was used, and in version B the two-string problem (Maier, 1931) was used. Insight problems require participants to overcome mental fixedness and to solve a problem in a novel way. The time limit was three minutes. In the candle task, participants were asked to attach a candle to the wall so that the wax would not drip onto the floor. A book of matches and a box of thumbnails are presented in the scenario of the problem. The solution is to nail the box to the wall, put the candle into the empty box, and finally, light the candle with the match. In the two-string problem, two strings were hanging from the ceiling and further away from each other than arm's length. Participants were required to find a solution to hold both strings simultaneously. The solution is to attach an object to one string and make it swing like a pendulum, then catch the swinging string while holding the other string. Participants scored one for a correct solution and zero for an incorrect solution. Moreover, participants' familiarity with the insight problem was examined.

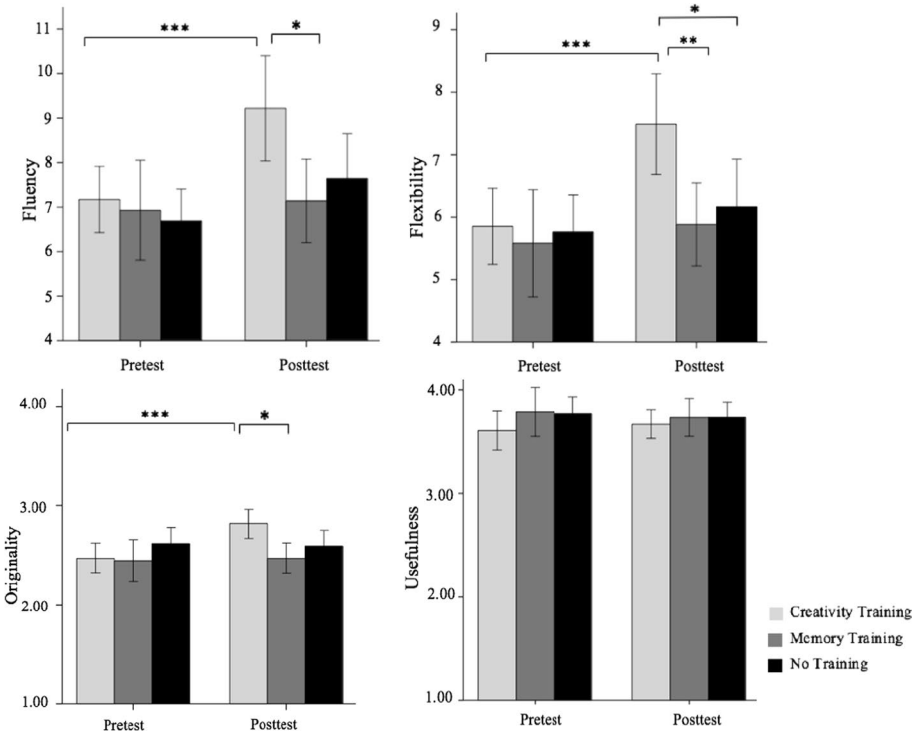


Fig. 1 Change of AUT performance from pretest to posttest per training group

Results

Data analysis

After data collection, we compared the training engagement and the training duration between the creativity training group and memory training group. Both groups showed high levels of engagement: participants in the creativity training group participated in 99.1% of the training days and those in the memory training group participated in 99.2% of the training days. Besides, no statistical difference was found between the creativity training group (11.36 ± 4.53 min) and the memory training group (9.50 ± 3.86 min) in training duration, $t(1) = 1.40$, $p = .169$.

To examine whether the creativity training improved participants' performance on the AUT, real-life problem, RAT, and well-being, mixed designed analyses of variance (ANOVAs) were conducted with training (creativity training vs. memory training vs. no-training) as the between-subjects factor, and measurement time (pretest vs. posttest) as the within-subjects factor. Simple main effects analyses using the Bonferroni correction were performed to test if there was a significant difference between groups and from the pretest to postest. For the main effects and interaction effects, effect sizes (η^2) were calculated. Effect sizes of $\eta_p^2 = 0.01$ represented small effect, $\eta_p^2 = 0.06$ represented medium effect, and $\eta_p^2 = 0.14$ represented large effect (Cohen, 1988). The results are presented in Figs. 1, 2, 3. For the insight problem, Fisher's exact tests were carried out to examine whether there was

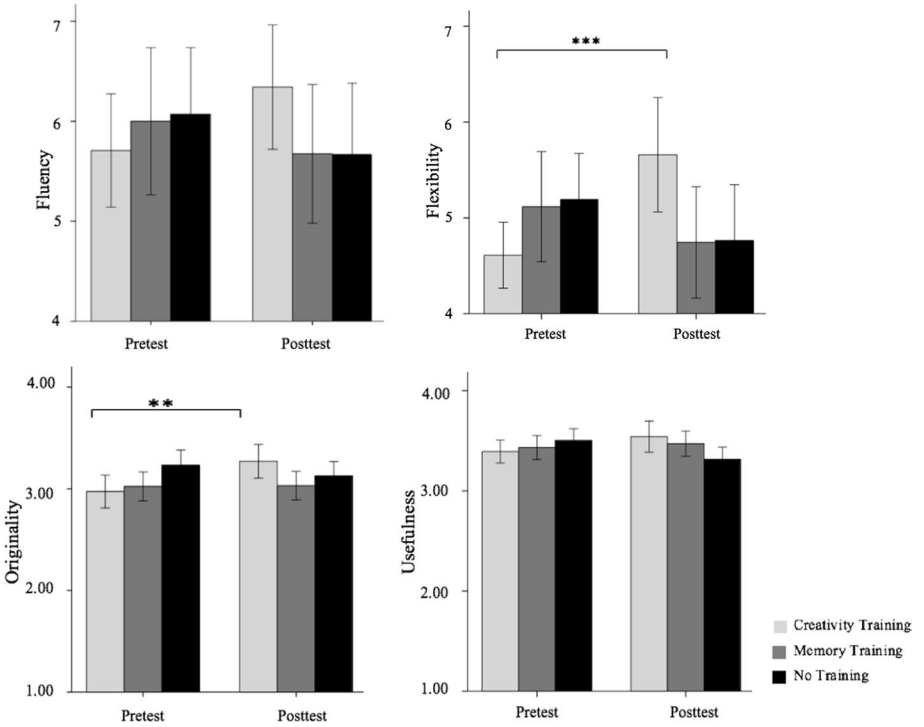


Fig. 2 Change of real life problem performance from pretest to posttest per training group

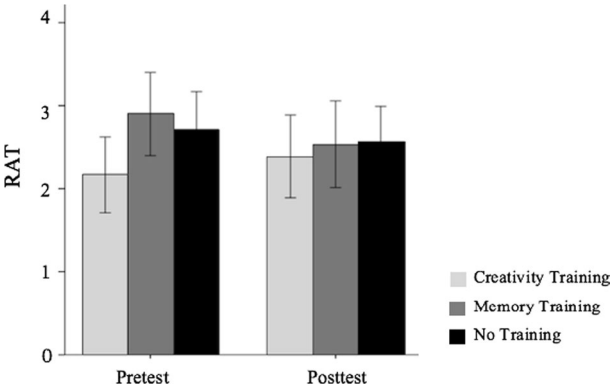


Fig. 3 Change of RAT performance from pretest to posttest per training group

Table 1 Descriptive Statistics of Participants' Performance on the Insight Problem in the Pretest and Posttest, after Checking for Familiarity

Training	*N*	Pretest		Posttest	
		Correct	Incorrect	Correct	Incorrect
Creativity training	13	3	10	2	11
Memory training	11	0	11	6	5
No-training	30	17	13	10	20

a significant difference between the pretest and posttest, and between the training groups. The results are represented in Table 1.

In addition, Pearson correlations were calculated between all of the indicators of the AUT and the real-life problem respectively. As shown in the Appendix 3, significantly high correlations (> 0.95) were observed between the creativity and originality of both the AUT and of the real-life problem. Hence, for each task only the mean originality score was included in the data analysis to avoid multiple testing.

AUT

Fluency. A significant interaction effect was observed between training and measurement time, $F(2, 123) = 3.43$, $p = .035$, $\eta_p^2 = 0.053$. The main effect for training was not significant, $F(2, 123) = 3.38$, $p = .097$, $\eta_p^2 = 0.037$, but a significant main effect was observed for measurement time, $F(1, 123) = 13.8$, $p < .001$, $\eta_p^2 = 0.10$. In the posttest, the creativity training group generated significantly more ideas than the memory training group, $p = 0.016$; no differences in the post-test were observed between the creativity training and the no-training group, $p = .102$, and the memory training and the no-training group, $p = 1.00$, respectively. Importantly, the creativity training group generated significantly more ideas in the posttest than pretest, $p < .001$, whereas no differences between the pretest and posttest were observed for the memory training, $p = .67$, and the no-training group, $p = .059$, respectively.

Flexibility. The results revealed a significant interaction effect between training and measurement time, $F(2, 123) = 3.32$, $p = .039$, $\eta_p^2 = 0.051$. No main effect of training, $F(2, 123) = 2.70$, $p = .071$, $\eta_p^2 = 0.042$, but there was a significant main effect of measurement time, $F(1, 123) = 11.2$, $p = .001$, $\eta_p^2 = 0.083$. In the posttest, the creativity training group generated ideas from more diverse categories than the memory training, $p = .008$, and the no-training group, $p = .039$; no difference was found between the memory training and the no-training group, $p = 1.00$. The creativity training group improved significantly from the pretest to posttest, $p < .001$, whereas no improvement was observed for the memory training, $p = .45$, and the no-training group, $p = .32$, respectively.

Originality. The interaction effect between training and measurement time was significant, $F(2, 123) = 3.94$, $p = .022$, $\eta_p^2 = 0.06$. No significant main effect was observed for training, $F(2, 123) = 2.26$, $p = .11$, $\eta_p^2 = 0.035$. The main effect for measurement time approached significance, $F(1, 123) = 3.79$, $p = .054$, $\eta_p^2 = 0.030$. In the posttest, the creativity training group generated more original ideas than the memory training group, $p = .005$, but no differences were observed between the creativity training and the no training group, $p = .11$, and the memory training and the no-training group, $p = .83$. While the creativity training group generated more original ideas in the posttest than pretest, $p = .001$, no differences in originality were found within the memory training, $p = .83$, and the no-training group, $p = .80$, respectively.

Usefulness. The interaction effect between training and measurement time was not significant, $F(2, 123) = 0.45$, $p = .64$, $\eta_p^2 = 0.007$. No significant main effects were observed for training, $F(2, 123) = 0.801$, $p = .451$, $\eta_p^2 = 0.013$, and measurement time, $F(1, 123) = 0.028$, $p = .869$, $\eta_p^2 = 0.000$.

Real-life problem

Fluency. The interaction effect between measurement time and training was non-significant, F (2, 123) = 2.91, p = .059, η_p^2 = 0.045. The results showed no main effects of training, F(2, 123) = 0.121, p = .886, η_p^2 = 0.002, and measurement time, F(1, 123) = 0.027, p = .869, η_p^2 = 0.000.

Flexibility. There was a significant interaction effect between training and measurement time, F (2, 123) = 7.94, p = .001, η_p^2 = 0.11. No significant main effects of training, F(2, 123) = 0.232, p = .793, η_p^2 = 0.004, and measurement time, F(1, 123) = 0.235, p = .628, η_p^2 = 0.002, were observed. In the posttest, no difference was found between the creativity training and the memory training group, p = .084, the creativity training and the no-training group, p = .097, and the memory training and the no-training group, p = 1.00. Importantly, participants in the creativity training group improved significantly from the pretest to the posttest, p = .001, whereas no improvement was found for the memory training, p = .21, and the no-training group, p = .15.

Originality. The results showed a significant interaction effect between training and measurement time, F (2, 123) = 4.15, p = .018, η_p^2 = 0.063. No significant main effects were revealed for training, F(2, 123) = 2.04, p = .135, η_p^2 = 0.032, and measurement time, F(1, 123) = 1.29, p = .258, η_p^2 = 0.010. In the posttest, no differences were observed between the creativity training and the memory training group, p = .071, the creativity training and the no-training group, p = .523, and the memory training and the no-training group, p = 1.00. The creativity training group improved significantly from pretest to posttest, p = .004, whereas no difference between the pretest and the posttest was observed for the memory training, p = .94, and the no-training group, p = .30.

Usefulness. The interaction effect between training and measurement time was not significant, F (2, 123) = 2.70, p = .071, η_p^2 = 0.042. No significant main effects were observed for training, F(2, 123) = 0.757, p = .471, η_p^2 = 0.012, and measurement time, F(1, 123) = 0.000, p = .998, η_p^2 = 0.000.

RAT

The interaction effect between training and measurement time was non-significant, F (2, 123) = 1.40, p = .25, η_p^2 = 0.022. Also, the results showed no significant main effect for training, F(2, 123) = 1.37, p = .259, η_p^2 = 0.022, and measurement time, F(1, 123) = 0.461, p = .499, η_p^2 = 0.004.

Insight problem

Participants' familiarity with the insight problems was checked prior to data analysis. Only participants who indicated unfamiliar with the insight problems at both the pretest and posttest were included in the data analyses.

As some cells had samples smaller than 5, Fisher's exact tests were performed to determine whether there were any differences between and within training groups. In the posttest, no significant differences were found between the creativity training and the memory

training group, $p = .082$, the creativity training and the no-training group, $p = .29$, and the memory training and the no-training group, $p = .29$, respectively. No differences between the pretest and the posttest were observed for the creativity training group, $p = 1.00$, the memory training group, $p = ?$ (Kappa is not computed as at least one variable in each 2-way table was a constant), and the no-training group, $p = .056$.

Discussion

The current study developed an online creativity training program and examined its effectiveness. The training employed a comprehensive approach and consisted of a series of self-instructional exercises, which were delivered online for five weeks. Upon following the online creativity training, significant improvements on several indices of divergent thinking performance were observed, whereas no differences were observed for the memory training group and the no-training group. On the AUT, the creativity training group generated significantly more ideas in the posttest than pretest. Importantly, for participants following the creativity training not only the idea quantity but also the quality was improved. In the creativity training group, participants generated significantly more original ideas in the posttest than the pretest ($p = .001$) and the memory training ($p = .005$). Moreover, regarding flexibility the creativity training group generated ideas from more diverse categories in the posttest than the pretest ($p < .001$), as well as than the memory training ($p = .008$) and the no-training group ($p = .039$). Similar findings were observed on the real life problem solving task, which further supported the effectiveness of the comprehensive training approach. Nonetheless, although the pre-posttest difference within the creativity training group was significant on the creative performance indices described above in both tasks, the between-subject comparison in the posttest between the creativity training and the two control groups was basically non-significant. Therefore, the results have to be interpreted with some caution.

But still, the current findings showed evidence of the effectiveness of a comprehensive online training. Although previous research has provided substantial evidence that creativity can be fostered through training, few studies have employed a comprehensive approach for training creativity (Ma, 2006; Scott et al., 2004a, 2004b). The 5-I training program encompassed five training components (Inclination, Ideation, Interaction, Identification, and Inspiration), which took into consideration the interaction and interdependence of multiple factors affecting creativity. Thus, the current online creativity training seemed to comprise key elements of effective training such as an emphasis on cognitive skills and strategies (Scott et al., 2004a, 2004b), integration of personal and environmental factors (Amabile, 1996; Rhodes, 1961; Simonton & Ting, 2010), and use of real life exercises (Beghetto, 2013; Doron, 2017).

The current study suggested the advantage of including both theory and practice in creativity training, which has found some support from previous research (Cano-Moreno et al., 2021; Gu et al., 2022b). In the study by Cano-Moreno et al. (2021), students first learnt creativity approaches or techniques and then they applied these techniques to solve and generate solutions for inventive problems. Their results showed that students generated twice the ideas compared to those generated before the training. Moreover, the current training

was advantageous in applying tools and exercises that provide cognitive strategies for creative thinking. During the five-week training, participants practiced a variety of exercises that aimed to foster different creative processes which seem to be particularly essential for divergent thinking. For example, the random connection technique, which emphasizes combining disparate concepts, was thought to contribute to enhancing associative thinking for the generation of original ideas (Malycha & Maier, 2017; Mednick, 1962). As suggested by previous studies, trainings focusing on developing specific creative processes are more effective in fostering creativity (Gu et al., 2022a; Scott et al., 2004a, 2004b).

Besides, the current online training seemed to be advantageous in its implementation of active learning strategy. Given that there was no interaction with the trainer, it can be challenging for the participants to maintain a higher motivation and get focused on the training (Taylor, 2002). During the online training, exercises provided after each technique allowed participants to actively practice the learnt techniques, which not only enhanced their motivation and engagement, but also facilitated their construction and internalization of the creative thinking skills (Hung & Chen, 2018). Further, participants practiced the exercises in a self-instructional manner, so they had control over the training, which might help them build a sense of self-efficacy of their creative capacity (Bartley & Golek, 2004; Chang, 2013). As supported by Chang (2013), a self-instructed online training facilitated students to analyse and solve problems in a divergent style. In addition, feedback (i.e., example solutions) was provided in the current training, which helped improve the quality of the training and promote participants' engagement. To sum, we assume that the active learning characteristics contribute to the success of the current online creativity training and provide insights for creativity training design in the future.

However, no training effects were observed on participants' convergent thinking skills as measured by the RAT and the insight problems. In these tasks, participants have to converge towards one correct solution that fits the task demand. Convergent thinking is likely developed if the online training activities put more emphasis on analysing and synthetizing information (Chang, 2013). Possibly, the training exercises included in the current training mainly contributed to participants' ability in freely generating solutions, but they didn't aid participants in evaluating all generated solutions and converging on a unique solution.

Limitations and future research directions

There are some limitations in this study. First, the sample of the current study mainly consisted of female university students. It seems that females are more likely than males to participate in online surveys (Moore & Tarnai, 2002; Singer et al., 2000). Specially, participants in this study were recruited at a university that has a larger proportion of females than males. An interesting question is whether the training results would differ with a more balanced sample.

Second, future research should focus more extensively on stimulating convergent creativity, and think about alternatives to measure participants' convergent thinking skills. In this study we measured participants' convergent thinking with the English version of the RAT, which might be difficult for non-native English speakers (Estrada et al., 1994), whereas in our study, the majority of participants were Dutch or German. For the insight problem, only a small sample was retained after checking of participants' familiarity with

the problems. Future research should think about alternatives to measure participants' convergent thinking skills.

Third, the current creativity training program consisted of a variety of techniques. It was unknown whether it was their combined effect or one of them that led to the significant improvement of participants' divergent thinking performance. Future studies could consider examining the effect of different single techniques.

Fourth, given that face to face interaction is limited in the online setting, it is difficult to develop personal relationships for example between students or between students and the trainer, and students need a higher motivation and self-discipline in online training context compared to traditional training context (Kumar, 2010; Taylor, 2002). Therefore, future research may think about how to boost interaction among the participants, for example, by creating space for social discussions to motivate a deeper understanding on the training content.

Furthermore, future research could consider taking the individual differences into account. Previous studies have suggested that individuals adapt differently with online training (Chen et al., 2011; Gu et al., 2022b). For example, Gu et al. (2022b) found that individuals with a field-dependent cognitive style benefited more from the online training using an active strategy than those with a field-independent cognitive style. It is suggested that future research could consider examining whether the 5-I online training, which is implemented either in an active or a passive learning strategy, differs in its effectiveness for enhancing creativity of students with individual differences.

Implications of the current findings

Our study highlights the benefits and feasibility of online training as a new norm for knowledge acquisition and learning. Because online training can be accessed by a wide range of population from distant locations, it can be used as an effective alternative to traditional way of learning and help continue education and training activities, especially during a pandemic when in-person classroom learning is unavailable.

The current findings provide important implications for educational and organizational settings. For teachers and organizational managers seeking to encourage student or employee creativity, they need to first provide students basic knowledge of the theoretical rationale of the creativity techniques, which are followed by specific practice.

The current training was delivered in a self-instructional format that allowed participants to control the pace of the training, which may contribute to a sense of self-efficacy with regard to creative capacity (Bartley & Golek, 2004; Huber et al., 1979). Hence, one avenue to train students creative thinking skills can be by following online training instructions in students own pace both in and outside the classroom.

The current research not only offers an array of readymade exercises that can be implemented to foster student creativity, it also suggests that techniques should be appropriately selected to suit the training aim. The current online training seems to be more effective in fostering students' divergent thinking (i.e., AUT, real-life problem).

Moreover, this online training can be applied to enhance creativity and innovativeness among employees. Creativity is one of a most in-demand skill in our competitive economic world, but little support for creativity development is provided (IBM, 2010; Lichtenberg

et al., 2008). With online training, organizations can offer creativity training access to their employees, without constraints of time and location.

Conclusions

Creative thinking has been considered as one of the most important 21st century skills. The ability to enhance creativity is crucial for personal and organizational success. Our study provided evidence regarding the effectiveness of online creativity training using a comprehensive training approach. The findings showed that online creativity training showed a tendency to significantly improve participants' performance in several key indices of divergent thinking (fluency, flexibility, originality). Taken together, the current study increases our understanding of enhancing creativity through online training and provides a new training approach, which may contribute to the enhancement of creativity in educational and organizational settings.

Appendix 1

See Table 2.

Appendix 2

Examples of the memory training exercise.

Table 2 The theoretical underpinnings of exercises in the online creativity training program

Exercises	The 5-I components				
	Inclination	Ideation	Interaction	Identification	Inspiration
Inspirational inventions	*			**	**
Finding differences		**		*	
Schema violation	**		**		
Ambiguous figures	**				
Stroop task	*	**			
Incomplete figures	*	**			
Constrained problem		**		*	
Word association	*	**		*	
SCAMPER		**	*	**	
Random connection		**	*	**	

In each exercise, ** means a strong focus on a specific component while * means a less strong focus

Example 1. In this exercise, you will be given 1 minute to look at a list of 15 words. Then, you'll be asked to recall as many of the words as you can.

eggs	drawing	rock	apple	focus
mission	favor	brain	flag	trial
partner	house	life	chair	ice

_____page break_____

Question: How many words from the list do you recall? Enter each word you remember.

_____

_____

_____

_____

_____

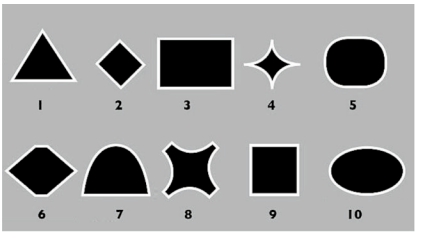
_____

_____

_____

_____

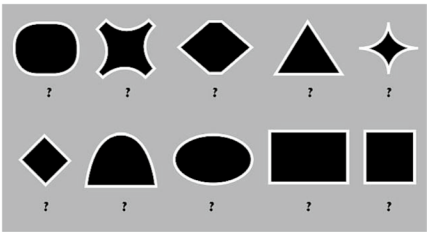
Example 2. Take three minutes to look at the following sequence of 10 shapes. Memorize them in the running order shown below, from 1 to 10. In the next page, you will find the shapes reproduced in a different sequence. You are required to number them in their original order.



_____page break_____

Below you will see the same shapes you have just memorized, but in a different order.

Try to number them in their original order.



Appendix 3

See Tables 3, 4.

Table 3 Correlations for the AUT

	1	2	3	4	5	6	7	8	9	10
1. Fluency_Pretest										
2. Flexibility_Pretest	.894**									
3. Originality_Pretest	.414**	.492**								
4. Creativity_Pretest	.391**	.472**	.981**							
5. Usefulness_Pretest	− .086	− .107	.221*	.235**						
6. Fluency_ Posttest	.454**	.410**	.115	.100	− .124					
7. Flexibility_ Posttest	.402**	.358**	.110	.089	− .117	.924**				
8. Originality_ Posttest	.098	.076	.202*	.201*	.241**	.337**	.388**			
9. Creativity_ Posttest	.106	.081	.220*	.222*	.250**	.312**	.356**	.992**		
10. Usefulness_Posttest	− .041	.031	.152	.179*	.468**	− .232**	− .224**	.105	.135	

* indicates $p < .05$ ** indicates $p < .01$, and *** indicates $p < .001$

Table 4 Correlations for the real-life problem

	1	2	3	4	5	6	7	8	9	10
1. Fluency_pre-test										
2. Flexibility_ pretest	.844**									
3. Original-ity_pretest	− .075	.030								
4. Creativ-ity_pretest	− .079	.024	.984**							
5. Usefulness_ pretest	− .114	− .102	− .020	− .004						
6. Fluency_post-test	.474**	.366**	− .087	− .102	− .048					
7. Flexibility_ posttest	.448**	.342**	− .026	− .036	− .045	.903**				
8. Original-ity_posttest	− .044	− .038	.075	.073	− .018	− .003	.009			
9. Creativ-ity_posttest	− .044	− .038	.081	.077	− .045	− .027	− .019	.977**		
10. Usefulness_ posttest	.173*	.219*	.159	.137	− .340**	.077	.043	.307**	.328**	

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Declarations

Conflict of interest None.

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