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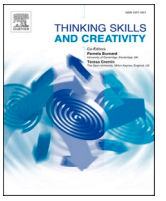

The Tripartite Thinking Model of Creativity

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ABSTRACT

This paper proposes a new concept of creativity, the Tripartite Thinking Model of Creativity (TTMC), which defines creativity as an interaction between three modes of thinking: logical, critical, and lateral. The TTMC Test is an experimental measure comprising three subtests collecting both quantitative and qualitative data. Inter-rater reliability results were mixed. Construct validity was assessed through confirmatory factor analysis, which showed overall goodness of fit. However, some factor loadings were low, indicating room for improvement in item design. Discriminant validity was evaluated through covariance structure analysis with the Abbreviated Torrance Test for Adults (ATTA). The correlation was low, implying that the TTMC Test and ATTA measure different constructs of creativity.

1. Introduction

It is almost impossible to define creativity in a single sentence. As Amabile (1996, p. 19) indicated, "we do not know enough to specify a precise, universally applicable definition of the term." In the absence of a clear definition, the field of creativity studies has yet to identify a widely accepted method for evaluating the construct, and diverse theories have been applied to do so. Gregory (2014, p. 392) pessimistically observed that "tests of creativity do not operationalize the construct of creativity very well."

The failure to operationalize creativity partially stems from its multifactorial nature. What do existing creativity scales measure in terms of creativity? Most researchers agree that psychometric tools must fulfill three requirements: first, and most importantly, the construct must be clearly defined (Smith, 2005); second, the evaluation criteria must be published (e.g., in manuals); and third, reliability and validity data must be reported. Sawyer (2012) establishes the necessity of defining the construct and operationalizing it for specific measurement. Thus, reviewing the theoretical constructs employed by existing creativity scales should clarify how each scale defines creativity.

1.1. Construct of creativity

Plucker et al. (2021) summarized creativity research from the perspective of creativity aspects and noted general trends in the field. Table 1 classifies the creativity measurements found in the literature.

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1.2. Creative processes

Cognitive psychologists have considered divergent thinking the basis of creativity since Guilford (1956) posited divergent thinking as the cornerstone of creativity. Divergent production abilities, one of the constructs of Guilford's (1967) "Structure of Intellect" model, are related to creative thinking. Guilford (1967, pp. 169–170) states that "creative potential (…) involves abilities outside the divergent-production," indicating that divergent thinking is not identical to creativity.

Torrance and colleagues have contributed greatly to creativity measurement research (Torrance, 1962; Torrance et al., 2008), and the The Torrance Test of Creative Thinking (TTCT; Torrance, 2008a, 2008b) has been widely used for gauging creativity in the domain of divergent thinking (Amabile, 1996; Plucker et al., 2021). The TTCT rates levels of divergent thinking according to four criteria: fluency—the ability to produce many ideas; originality—the capacity for uncommon, new, or unique ideas; flexibility—the aptitude to produce many various ideas; and elaboration—the ability to embellish ideas with details (Carson, 1999; Goff & Torrance, 2002).

Despite the popularity of divergent thinking tests, this construct has drawn severe criticism. Moreover, focusing on divergent

Table 1
Creativity constructs: summarized by authors from Plucker et al. (2021)

Category	Sub-Category	Constructs of Creativity	Author	Measurement of Creativity	Definition of Constructs
Creative Processes		Divergent Thinking	Guilford (1967)	Structure of the Intellect Model (Divergent production)	Not shown
		Divergent Thinking	Torrance (2008a; 2008b)*	Torrance tests of creative thinking (TTCT)	Not shown
		Divergent Thinking	Getzels & Jackson (1962)	Getzels & Jackson (1962)	Not shown
		Divergent Thinking	Wallach & Kogan (1965)	Wallach & Kogan (1965)	Not shown
		Scientific Structure Creativity Model (SSCM)	Hu & Adey (2002)	Scientific creativity test	Inadequate
The Creative Person	Personality Scales	Not shown	Gough (1979)	Rating by others (expert judges, faculty members, etc.)	Not shown
		Not shown	Domino (1994)	Rating by others (colleague or faculty) and self-rating	Not shown
		Not shown	Kaufman & Baer (2004)	Self-rating	Not shown
		Not shown	Runco et al. (2017)	Six self-assessment scales	Not shown
		Not shown	McCrae & Costa (1997)	Creativity assessment has not been conducted	None
	Activity Checklists	Not shown	Hocevar (1979)	Self-rating	Not shown
		Not shown	Carson et al. (2005)	Creativity achievement questionnaire	Not shown
		Divergent Thinking	Runco et al. (2001)	Runco ideational behavior scale	Not shown
		Not shown	Kaufman (2012)	Kaufman Domains of Creativity Scale	Not shown
		Not shown	Renzulli et al. (2021)	Scales for rating the behavioral characteristics for superior students	Not shown
	Attitudes	Not shown	Basadur et al. (2002)	Creativity assessment has not been conducted	None
		Not shown	Runco et al. (2017)	Creativity assessment has not been conducted	None
		Divergent Thinking	Hao et al. (2016)	Malevolent Creative Behavior Scale	Inadequate
		Not shown	Tierney & Farmer (2011)	Six-item creativity measure	Not shown
		Not shown	Beghetto (2006)	Creativity assessment has not been conducted	None
		Not shown	Beghetto et al. (2011)	Rating by others (teachers)	Not shown
		Not shown	Karwowski (2014)	Creativity assessment has not been conducted	None
Creative Products		Not shown	Amabile (1982)	Consensual assessment technique (CAT)	Not shown
		Not shown	Reis & Renzulli (1991)	Student product assessment form	Not shown
		Creative Product Analysis Matrix (CPAM)	Besemer & O'Quin (1999)	Creative product semantic scale (CPSS)	Besemer & Treffinger (1981)
Creative Environments		Not shown	Amabile et al. (1996)	Rating by others (managers & experts)	Not shown
		Not shown	Forbes & Domm (2004)	Self-rating	Not shown

* The first version of TTCT was developed in 1966 (Kim, 2006)

thinking may limit the depth and range of creativity research. For example, Plucker et al. (2021) emphasize divergent thinking as only one part of creativity. Runco (1993) asserts that divergent thinking is not at all synonymous with creativity and is likely an unsuitable criterion in creativity research. The TTCT (Torrance et al., 2008) counters such critique with its 13 subscales (including expressiveness, storytelling articulateness, and humor); however, these subscales were added as supplementary measures, and exactly how they respond to the critique is not clarified.

Other divergent thinking tests (e.g., Getzels & Jackson, 1962; Wallach & Kogan, 1965) encounter similar construct-related problems. Hu and Adey (2002) proposed the three-dimensional Scientific Structure Creativity Model (SSCM), with scientific creativity as a construct. However, they fail to explain the validity of the dimensions of process, product, and trait–drawn from the four typical dimensions of creativity–as subscales of scientific creativity.

1.3. The creative person

"Instruments intended to measure personality correlates of creative behavior are generally designed by studying individuals already deemed creative and then determining their common characteristics" (Plucker et al., 2021, p. 51). In this section, we investigate the assumed constructs of creativity. (The focus is not the personality scales, but how creativity is identified.)

As shown in Table 1, the category of "The creative person" has three subcategories. First, "Personality scales" mainly employ either self-rated or other-rated assessments of creativity with no explanation of the constructs of creativity. In Gough's (1979) Creative Personality Scale, creativity is assessed by others. In Domino (1994), creativity is assessed by others and through self-rating. Kaufman and Baer (2004) and Runco et al. (2017) measure creativity by self-assessment. McCrae and Costa (1997) did not implement a measure of creativity.

Second, in "Activity checklists," participants are sometimes asked to report on their creative experiences according to checklists, while some studies employ the reports of others, such as teachers rating students' creative activities, but do not provide detailed explanations of how creativity is indicated by the presence or absence of any particular activity. In Hocevar's (1979) Creative Behavior Inventory, creativity was assessed through college students' self-evaluation of past experiences in six "creative" areas (e.g., fine arts, crafts, literature). Carson et al. (2005) developed the Creativity Achievement Questionnaire to check for experience in 10 domains, including drama, writing, and humor, but how each item constitutes creativity is not described. Runco et al. (2001) developed the Runco Ideational Behavior Scale to address the predictive validity weaknesses of divergent thinking tests, but raised the question of whether divergent thinking is the same as creativity. The Kaufman Domains of Creativity Scale consists of 50 items, self-assessed on a five-point Likert scale (Kaufman, 2012), with no explanation of how these items constitute creativity. Renzulli et al. (2021) developed the Scales for Rating the Behavioral Characteristics of Superior Students, with evaluations conducted by faculty members on items spanning 14 areas, including creativity. However, there is no explanation of the construct.

Third, in "Attitudes," the relationship between creativity and attitudes toward creativity has been widely studied. Basadur et al. (2002) conducted a survey of managers and professionals using the Preference for Active Divergence Scale and the Preference for Premature Convergence Scale. However, creativity was not clarified. Runco et al. (2017) developed the Creative Attitudes and Values Scale to assess attitudes and values toward creativity. Several measures that may influence creativity were also developed, but none were used to assess creativity. Hao et al. (2016) developed the Malevolent Creative Behavior Scale with 13 observable variables. However, all 13 items were based on divergent thinking, again drawing the criticism that divergent thinking is not identical to creativity. Tierney and Farmer (2011) examined the relationship between creative self-efficacy and creativity. Tierneyet al.'s (1999) six-item scale, used in this study, is a supervisory assessment of creativity. Beghetto's (2006) three-item measure of creative self-efficacy does not assess creativity. Beghetto et al. (2011) used multiple regression analysis to examine the relationship between creative self-efficacy and creativity, as evaluated by others (teachers). Karwowski (2014) explores the creative mindset (10 items) and the creative self-concept (11 items), but the relationship with creativity has not been explained.

1.4. Creative products

Measures of creative products aim to rate the quality of products involved in creative activities, such as writing, drawing, and student portfolios. Given that these products are visible and readily available, they are categorized as an "objective" method for capturing the signals/substitutes of creativity. Those with highly rated creative products are considered creative. The Consensual Assessment Technique (CAT; Amabile, 1982) is a popular measure of creativity based on creative products (Kaufman & Baer, 2012; Plucker et al., 2021; Reiter-Palmon et al., 2012). Subject experts, such as instructors, teachers, and judges, are asked to rate the level of products (Amabile, 1982); without explaining the reasons for their ratings, they are asked to arrive at a consensus (Kaufman & Baer, 2012).

According to Plucker et al. (2021, p. 55), "The CAT is an attempt to solve the 'criterion problem' in creativity research." In other words, the CAT is not concerned with the construct of creativity. While the CAT does present "a clever solution for the 'criterion problem'" (Plucker & Makel, 2010, p. 59), construct avoidance is not an appropriate strategy for scale development. In addition, if there is no obligation to explain the reasons for the evaluation, it would be difficult to use the CAT in situations requiring accountability.

Reis and Renzulli (1991) developed the Student Product Assessment Form, comprising nine criteria for teachers to assess the creativity of students' work. In contrast to the CAT, evaluation criteria are clearly stated, providing some explanation as to why students' work is or is not assessed as creative. However, there is no explanation of how the nine criteria affect the constructs.

Besemer and O'Quin (1999) developed the Creative Product Semantic Scale (CPSS) to evaluate creativity based on product quality.

The CPSS utilizes three criteria for rating product quality: novelty, resolution, and elaboration and synthesis. The unique feature of this scale is that it is developed based on the Creative Product Analysis Matrix (CPAM; Besemer & Treffinger, 1981) conceptualized to measure product creativity. The three criteria were derived from a review of research on measuring product creativity.

The assessment of creative products is often an attempt to evaluate creativity through creative product quality, which may or may not reveal creativity, as creativity lies within people, not products. Therefore, the measurement of creative products inevitably fails to include means for measuring creativity and functions as merely a proxy or substitute measure. However, as seen in the development of the CPAM and CPSS, first determining the construct of creativity, and then developing a scale, can be useful for developing a new creativity scale.

1.5. Creative environments

Creative environment scales view creativity in relation to the environment and attempt to measure the interaction between creativity and the environment. This section focuses not on scales that measure workplace environmental factors of creativity, but on how the studies measure creativity.

Assessing the Climate for Creativity is a scale developed to assess factors that promote or inhibit creativity in an organization's work environment (Amabile et al., 1996). To measure organizational creativity, the projects with the highest and lowest creativity were nominated by the surveyed companies relative to the extent to which the project or project members generated novel and useful ideas. The creativity of nominated projects was then re-evaluated by experts who were familiar with the projects. Neither the construct of creativity nor its evaluation criteria are described. Both the nomination of projects with high and low creativity by managers and the reassessment of nominated projects by experts are conducted by others (vs. self-rated). Forbes and Domm (2004) requested 158 engineers and scientists to think of an important project they had recently completed, then asked them about six factors, including mental involvement and intrinsic motivation. They were also asked about their creativity and whether they had come up with new and innovative solutions to the project's problems. No explanation of the construct of creativity was given.

1.6. The current study

Plucker et al.'s (2021) review explored constructs previously assumed in creativity research. Since the purpose of the current study was not to provide an exhaustive review of creativity scales, studies not covered by Plucker et al. (2021) were excluded. For example, Mednick (1962), mentioned in Plucker and Makel (2010), is no longer discussed in Plucker et al. (2021), and was therefore omitted from the current study. Acar and Runco (2015) was also excluded; it is described in Plucker et al. (2021) without reference to its contents.

Even though these selective reviews are imperfect, a general trend has emerged. Except for a few studies (e.g., Besemer & O'Quin, 1999; Hu & Adey, 2002), most measure creativity without clarifying the construct. Thus, they do not satisfy the most important requirement of scale development, namely, the clear definition of the construct. If the construct is not defined, there is ambiguity regarding the type of creativity being measured. Why is this the case? "It's because creativity—as we use the term in everyday language—is not a scientific concept; it's a culturally and historically specific idea that changes from one country to another, and from one century to another" (Sawyer, 2006, p. 36).

Some researchers (e.g., Hao et al., 2016) have examined constructs using exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) to extract common factors from multiple observable variables that are likely to be creative and test their construct validity. However, there is an unaddressed need for a theoretical explanation of the derived constructs. If different observable variables are set for the same participants, the derived constructs may also change, making it difficult to explain which construct is more plausible. Sawyer (2006) further argues that before creativity can be dealt with scientifically, it is necessary to explain creativity because its definition can vary due to cultural and historical context. The priority is deriving the construct theoretically, despite its difficulty. Next, the observable variables are developed, and reliability and construct validity are verified. If undesirable results are obtained in terms of reliability and validity, the observable variables should be changed. If the reliability and validity cannot be verified even after changing the observable variables, the procedure for developing the construct should be checked for errors. By repeating this process, a more precise theory can be distilled.

Even though creativity is a complex and elusive concept, it is not desirable for creativity research to be conducted without defining the construct of creativity. Therefore, we aimed to tackle two major challenges. The first is to derive the theoretical construct of creativity. Creativity can be perceived differently depending on who is being creative and in what situation. Our main field of study and expertise is management science, including organizational behavior and industrial/organizational psychology. Therefore, we will attempt to derive a theoretical construct of creativity from the perspective of creativeness required for people who belong to organizations such as companies. The second challenge is to develop a creativity measurement test that corresponds to the newly derived construct of creativity and test its consistency with the construct. If this can be done, it will be possible to discover creative employees within organizations. It may also be possible to measure the effectiveness of the training by measuring the creativity levels before and after the training.

2. Development of the Tripartite Thinking Model of Creativity

2.1. Target context

In defining creativity in the current study, it is important to start by narrowing down the target context. First, we consider who will be creative and in what situations; next, we clarify which aspects of creativity will be targeted.

2.1.1. Target creativity: people, situation

There are two perspectives on creativity: one focuses on geniuses or eminent people who have greatly impacted history and society; the other focuses on creative activities demonstrated by ordinary people in their everyday activities. Maslow (1959) distinguishes between the two in terms of special-talent creativity and self-actualized creativity. Special-talent creativity is exhibited by geniuses with extraordinary talents and abilities, such as poets, composers, inventors, and artists. Self-actualizing creativity may be possessed by anyone and is demonstrated in everyday situations. This kind of creativity would be better described as "everyday creativity." De Bono (1992) classified creativity into everyday creativity and specific creativity. Everyday creativity occurs in all situations, wherein we think about things without requiring any conscious effort. Specific creativity requires conscious effort and is needed in situations where the aim is relatively easy to specify. We combine Maslow's (1959) and De Bono's (1992) classifications as a typological axis, organizing them in four 2 x 2 columns, as shown in Table 2.

There are three perspectives for the classification shown in Table 2. The first is who exhibits creativity. Special-talent creativity is that of eminent people or geniuses, while specific and everyday creativity are exercised by ordinary people. The second is the situation in which the creativity is exercised. Special-talent and specific creativity are exercised in problem-solving situations for which the goal is clearly identified. Everyday creativity is exercised in all aspects of daily life and does not necessarily have a clear goal in mind. The third is whether creativity requires conscious effort. Special-talent creativity also requires hard work and training, relentless criticism, and a high standard of workmanship. Specific creativity requires a systematic and conscious effort to create new ideas and concepts. Everyday creativity is improvisational, requires no conscious effort, and is unconsciously exercised in everyday life (De Bono, 1992; Maslow, 1959). The creativity exhibited by eminent people or geniuses in their daily lives was classified as everyday creativity.

Our main research field of study is organizational human resources in the context of management science, such as organizational behavior and industrial/organizational psychology. In organizations, creativity is needed for developing new products and services or problem-solving in business activities, such as project delays or product defects, and when there is no right answer. This is termed "creativity for problem-solving," where the purpose and problem are clearly recognized, or, at the very least, a general idea of the problem is shared. According to the classification in Table 2, this is categorized as specific creativity.

2.1.2. Target creativity: Aspects

Rhodes (1961, p. 307) discusses the four "Ps," Process, Product, Person, and Press: "Each strand has unique identity academically, but only in unity do the four strands operate functionally." The relationship between the four Ps may be organized as shown in Fig. 1.

So far, measures of creativity products, personality, and behavior have been reviewed and were deemed capable of distinguishing between creative and non-creative persons. No matter their effectiveness in this regard, however, they can only characterize creative individuals, rather than gauge their actual level of creativity. Thus, it is necessary to shift the focus from exogenous elements, such as creative products, personality, and behavior, to endogenous elements of cognition and mental function. Thus, the current study focuses on process, specifically the thinking process determining the nature of creativity.

2.2. Construct of the Tripartite Thinking Model of Creativity

Creativity has a deep association with problem-solving (Amabile, 1996; Finke et al, 1992; Mayer, 1992; Runco, 2004). Drawing on previous studies (e.g., Bransford & Stein, 1993; Mumfordet al., 1991; Proctor, 2019), three core steps to creative problem solving can be distilled: defining problems, producing solutions, and theorizing solutions (Fig. 2).

In the problem definition stage, the current and desired situations are recognized. The outcomes of this stage are models (e.g., charts, images, mathematical formulae, and diagrams [Alexander, 1964]). The current situation model can be termed the "as-is model", and that of the desirable situation the "to-be model." The gap between the "as-is" and "to-be" models is the problem. In other words, the problem is defined through the modeling of problem situations. The solution production stage is aimed at finding or generating numerous ideas to move from "as-is" to "to-be" and selecting one or more appropriate ideas. This stage requires the most creativity of the three, as this is where solutions are found to problems with no clear answers. In the solution theorization stage, the selected ideas are arranged as a solution plan that can be implemented. The solution plan must be rational and persuasive to garner the

Table 2
The four quadrants of creativity: Shown by whom? In what situations?

	In what kind of situations?	
Whose Creativity?	Specific situations (Requires effort)	Everyday life (Requires no effort)
Eminent people, Geniuses	Special-talent creativity	Everyday creativity
Ordinary people	Specific creativity	Everyday creativity

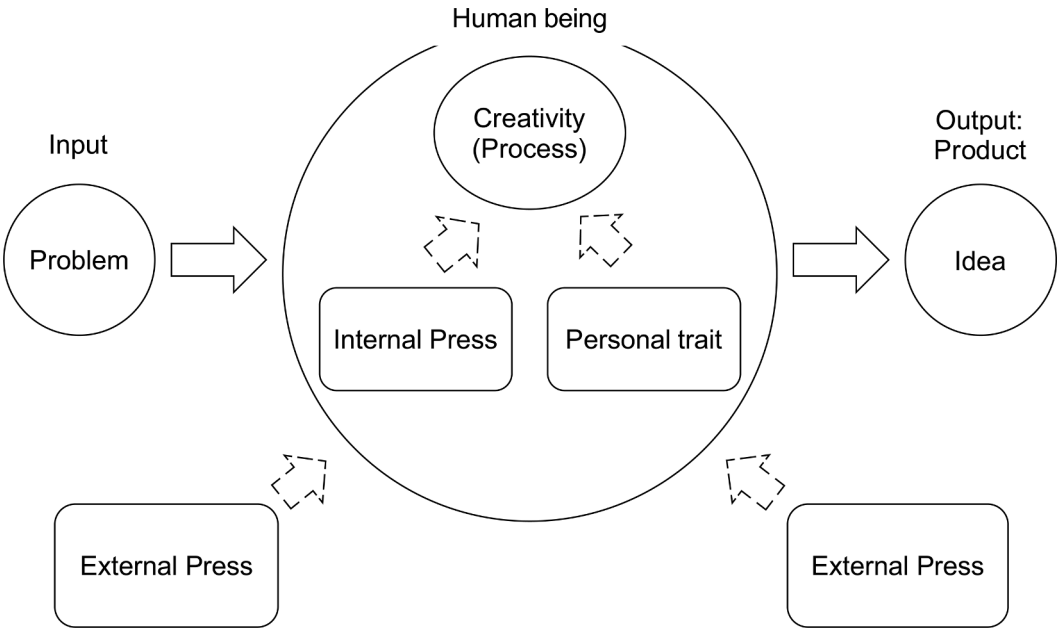


Fig. 1. Relationship among 4Ps

cooperation of others (e.g., customers, managers, and associates). The stages generally flow chronologically, but there are sometimes returns to the previous stage, if necessary. Creative problem solving, as typified by "bounded rationality" (Simon, 1996, 1997) and "wicked problems" (Rittel & Webber, 1973), does not involve easy-to-find solutions. Therefore, it is possible to go back and forth between the three stages many times. For example, if a solution plan is judged unfeasible when evaluated in the solution theorization stage, the process goes back to the solution production stage, and a new solution plan is formulated. If the evaluation of the current situation is found to be incorrect in the solution production stage, the problem definition stage should be revisited. If a problem is found with the current understanding during the solution theorization stage, instead of going back to the solution production stage, it is possible to return directly to the problem definition stage.

Considering these three stages in terms of human cognitive and thinking processes, three common core activities have surfaced. The first is organizing logically. In the problem definition stage, the elements constituting the problem are selected, their interrelationships identified, and the "as-is" and "to-be models" are described logically. In the solution production stage, the most rational solution plan is selected from several alternatives. In the theorization of solutions stage, the reasons for selecting the alternative and implementations plan are logically organized. The second activity is evaluation. The output of each core stage is evaluated to determine, for example, whether the models describe the problem situation correctly, whether the selected alternative offers the best solution, and whether the implementation plan is practical. The third activity is the change of viewpoints and ideas. In each stage, when it becomes impossible to advance using shared viewpoints and ideas, they should be changed. In other words, three kinds of thinking (i.e., logical thinking for logical organization, critical thinking for evaluation, and lateral thinking for change) are mandatory in every stage. The process is illustrated in Fig. 3.

2.3. Functions of the three ways of thinking

2.3.1. Logical thinking

Not many academic papers discuss logical thinking. For example, among the academic papers registered in PsycINFO/PsycARTICLES since January 1, 2011, only six were found with "logical thinking" in the title (retrieved on August 18, 2021). In the field of school education, Jawad et al. (2021, p. 199) describe logical thinking as "an individual mental activity aimed at making a decision or reaching a solution to a problem, and it is a process that takes place to reach results through knowing specific introductions." Swestyani et al. (2018) state that logical thinking is a rational process of the brain by which people find correct conclusions.

In Japan, the term is often used in the business domain. For example, Teruya and Okada (2001) propose the tools of logical thinking from the perspective of a consulting firm. Mogi (2004), a brain scientist, defines logical thinking as categorizing, organizing, and assembling complex concepts in one's mind to make them easier to understand, while Noya (2006), a philosopher, argues that logical ability relates to the accurate understanding and operationalization of the reasoning of logic, which is different from thinking. In other words, logical thinking and logical reasoning are distinct concepts.

From the above, it is necessary to define logical thinking in the current study relying on data modeling. In management science, a model is a systematic description of concepts and causal relationships that cannot be seen as real and can be shared and understood as knowledge (Nonaka & Konno, 2003). Sato's (2009) T-formed ER data modeling method draws on work in the fields of linguistic

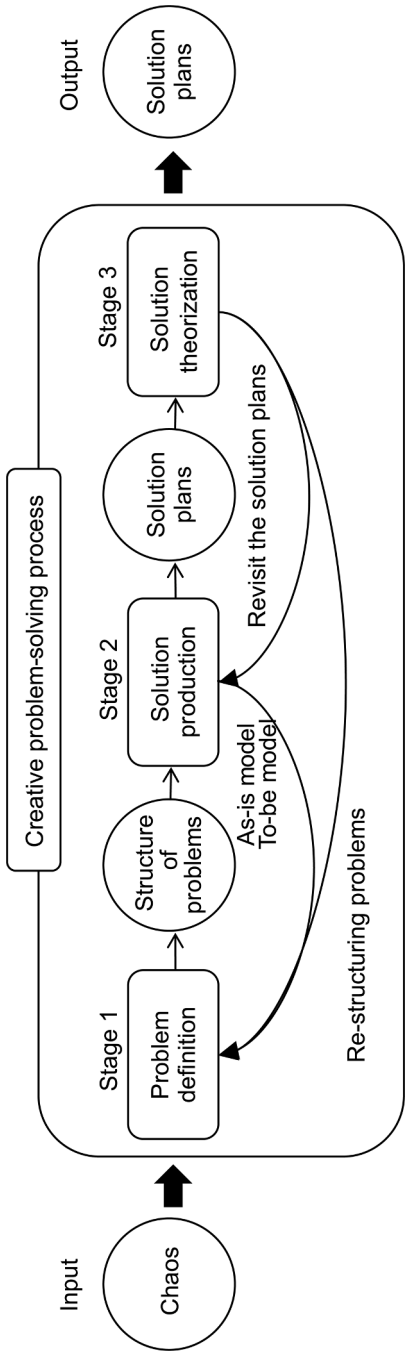


Fig. 2. Creative problem-solving process

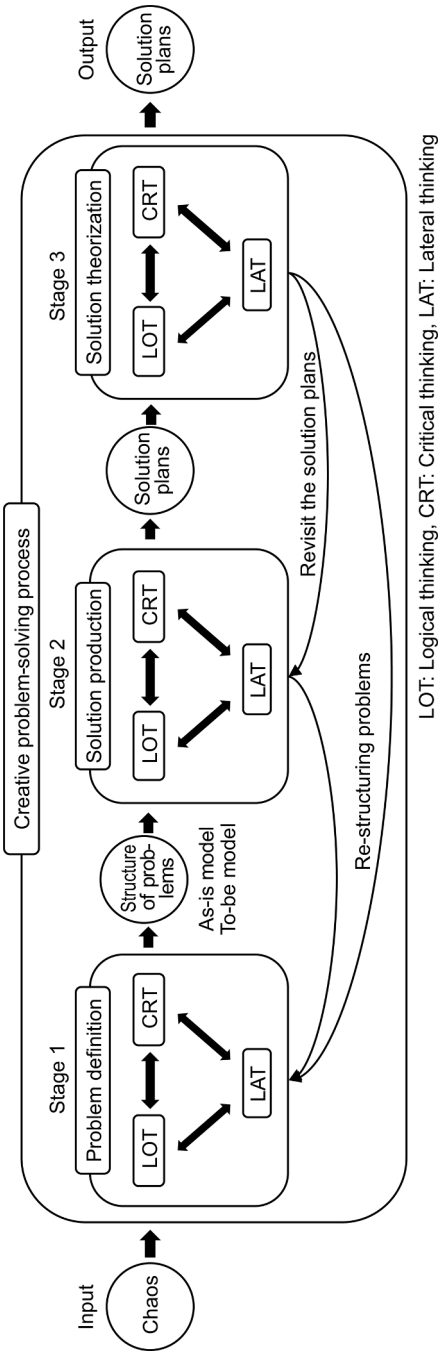


Fig. 3. Detailed creative problem-solving process.

philosophy and mathematical logic by Frege and Wittgenstein, among others, from the perspective of systems engineering, to represent corporate operations as data models. According to Sato (2009), models are mechanical, formal, and accurate descriptions of the meaning and structure of information transmitted in business and management processes.

There are three requirements for this definition: there must be rules for model development, the model must be consistent and complete, and the model's validity must be verified by comparing it with real business and management processes. The as-is and to-be models are terms used in enterprise architecture (Zachman, 1987). The concept of the model in the current study relies on Sato's (2009) requirements; the "model" in the current study is a logical representation of what a person perceives in accordance with some rules. A model can be expressed in the form of sentences or mathematical expressions, or as visual images such as diagrams or pictures.

In this study, logical thinking is defined as the cognitive skill required for identifying elements that form the structure of a problem, finding relationships between factors, and structuring the framework for solutions in rational ways. In a chaotic problem situation, it is important to clarify the problem structure by clarifying what is happening, who the people involved in the problem are, what their positions and relationships are, and what will happen if the situation continues.

2.3.2. *Critical thinking*

Previous studies on critical thinking tend to regard the concept as a variety of skills, including evaluation, logical thinking, attitude, and knowledge, among others. According to Glaser (1941), critical thinking includes three factors: an attitude of thoughtful consideration, knowledge of the methods of logical inquiry and reasoning, and the skills to apply those methods. However, attitude, knowledge, and skill application are not "thinking," and Glaser's (1941) definition of critical thinking can thus be understood as the ability to use these three items. Ennis (1962, p. 81) defined critical thinking as "the correct assessing of statements," clarifying three dimensions of critical thinking: logical, critical, and pragmatic.

The logical dimension applies to understanding the meanings of statements, using proper logical operators, and basic knowledge of the field in which the statements are made. The critical dimension covers judging statements, while the pragmatic dimension judges whether the statements exactly match the purpose for which they are made. Ennis redefined critical thinking as "reasonable reflective thinking focused on deciding what to believe or do" (1987, p. 10). Ennis (1987) further distinguishes 14 dispositions (e.g., seek a clear statement of the thesis or question, seek reasons, and try to be well informed) and 12 abilities (e.g., focusing on a question, analyzing arguments, and asking and answering questions for clarification and/or challenge) as subscales of critical thinking. While Ennis (1962) focused on only "assessment," he later extended critical thinking to a wide concept encompassing disposition, reasoning, and decision-making, among others (Ennis, 1987). Zechmeister and Johnson (1991) defined critical thinking as logical and non-biased thinking based on proper standards and evidence, while noting that critical thinking had three elements: the attitude to observe the problem attentively and deliberate on it carefully, the knowledge about the methods of logical exploration and reasoning, and the skill which could be applied to those methods. It seems that the previous definitions of critical thinking have extensive conceptions over "thinking."

Critical thinking in this study is defined in terms of the evaluation aspect, as it must be distinguished from the logical thinking mentioned above. Critical thinking is the cognitive ability to evaluate the line of reasoning, judge the accuracy based on suitable standards, and discover mistakes in the logic. The "standards" are mainly domain-specific knowledge. For instance, when critical thinking evaluates Socrates' syllogism, the rules of deductive inference are used as the standards. When critical thinking evaluates the source codes of the computer programs, the knowledge of the programming language and the algorithm are used as the standards. The output of critical thinking is the result of evaluation. While using a wrong standard or not having domain-specific knowledge, it is impossible to evaluate claims correctly.

Logical thinking in this study comprises selecting elements, finding relationships, and remaking models. It does not include evaluation. Critical thinking in this study involves evaluation but does not include the selection of elements, finding relationships, and remaking models. When the situation models are recreated by logical thinking, critical thinking immediately evaluates them. When the result of the evaluation by critical thinking is "incorrect," the models will be recreated by logical thinking.

2.3.3. *Lateral thinking*

Lateral thinking is a skill that can generate unique ideas (De Bono, 1967). Lateral thinking draws on the understanding that many problems require a different perspective to solve them successfully (Proctor, 2019). De Bono does not define lateral thinking clearly. However, based on several explanations and examples (e.g., De Bono, 1967, 1970, 1971, 1990, 1992), it can be concluded that lateral thinking comprises three concepts: change of cognitive patterns, humor, and future orientation. The output of lateral thinking is unique ideas; a change in cognitive patterns will directly reflect on the output. De Bono did not reveal how humor and future orientation function; however, it can be assumed that they represent viewpoints and attitudes required for identifying a pattern change. Kotler and de Bes (2003) indicated that lateral thinking is a way of thinking which changes models. It can be noticed from the above that the change of cognitive patterns is the key element of lateral thinking.

It follows from the belief that lateral thinking is the cognitive ability to produce unconventional patterns that go unnoticed in habitual recognition and common sense. With the help of lateral thinking, we can generate many types of novel and idiosyncratic ideas (De Bono, 1967). Based on the above discussion results, lateral thinking in this study is defined as thinking that goes beyond existing cognitive patterns of things to create new patterns.

2.4. *Definition of the Tripartite Thinking Model of Creativity*

Fig. 4 illustrates the process of interaction of the three ways of thinking.

Input is the trigger that activates creativity. It may be a very confusing problem that is very difficult to solve. Output is the outcome of creativity. It may be a solution plan. The arrows show the transfer of the process, while the circles reveal the input/output parameters between the three modes of thinking. For instance, the model, the output of logical thinking, is also the input of critical and lateral thinking. For critical thinking, it is an object of evaluation. For lateral thinking, it is a basic design to change or produce other unique patterns. The result of evaluation, the output of critical thinking, is also the input of logical and lateral thinking. If it is "Wrong," logical thinking must remake the model, and lateral thinking has to generate another idea. The idea, the output of lateral thinking, is also the input of logical and critical thinking. Logical thinking reorganizes it logically to a specific executable plan. For critical thinking, it is an evaluation object. The transition between the three ways of thinking happens instantly, and it is difficult to determine which way of thinking is working at a given point in time. Moreover, all three ways of thinking are not always activated; only one or two may be activated, depending on the situation. Because of the immediate change of the thinking process, it may be misinterpreted as two or three ways of thinking functioning simultaneously.

In sum, creative output can be produced through mutual exchange of information during the three ways of thinking. De Bono (1967, 1971) claimed that vertical thinking (i.e., logical and critical thinking) or lateral thinking alone could not foster creativity, given that lateral thinking produces unique ideas and vertical thinking develops it. The interaction among the three ways of thinking is the nature of creativity.

In this study, creativity is defined as *the interaction of three ways of thinking: logically, critically, and laterally*. This is termed the Tripartite Thinking Model of Creativity (TTMC; Horikami, 2012).

3. Development of the Tripartite Thinking Model of Creativity Test

3.1. Study 1: Preliminary investigation

For the TTMC-based creativity measurement, a preliminary survey was conducted to determine what kinds of test questions should be submitted, what types of answers participants should give to the test questions, how answers should be scored, and how much load participants should bear.

3.2. Methods

3.2.1. Participants

The preliminary survey was conducted in December 2010 as a paper-and-pencil take-home test for undergraduate and graduate students from universities in the Kansai area in Japan, who had offered their cooperation. A total of 19 participants were included: 10 undergraduates, two general graduate students in the master's program, one general graduate student in the doctoral program, two working professional graduate students, three working doctoral students, and one working master's student from another university. There was no remuneration for their cooperation; they were volunteers. Informed consent was provided at the time of recruitment.

3.2.2. Materials

Test questions were devised by one subject expert in personal assessment and one graduate student majoring in creativity. The test questions consisted of three types: logical, critical, and lateral thinking.

The logical thinking section consists of nine questions. The first three questions are short sentences of about five lines, and participants are asked to answer whether each sentence is a fact or a non-fact. The next three questions are conjunctions: short sentences of about five lines with blank spaces, and the participants are required to fill in the appropriate conjunctions. The last three questions are modeling tasks, and the sample question is shown in Fig. 5. After reading a description of the logic tree and an example of how to write it, participants were asked to write a model by logic trees according to the question for themselves.

The critical thinking section also comprises nine questions. The first three questions present opinions that are common in daily life, and participants are asked to refute them in about 100 words. The next three questions ask participants to criticize a certain argument

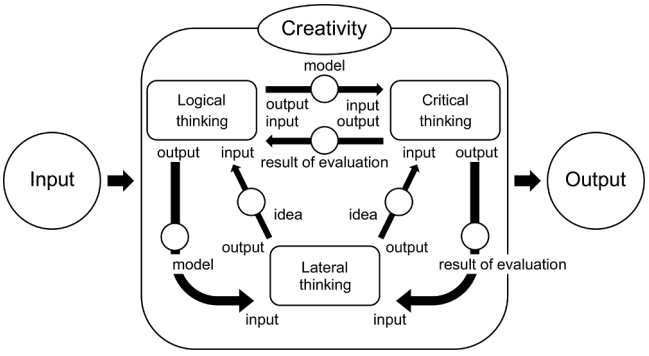


Fig. 4. Process model of the Tripartite Thinking Model of Creativity

presented in a text in about 100 words. In the last three questions, participants are presented with illustrations of things they see in their daily lives. A sample question is shown in Fig. 6, an illustration of a post box with two mailbox openings (a type of post box common in Japan). Participants are asked to point out problems with them in about 100 words.

The lateral thinking section also comprises nine questions. In the first three questions, participants are presented with a five-line text describing a problem situation that could occur in the management field. They are asked to solve the problem in about 100 words. In the next three questions, participants are presented with pictures or illustrations of two or more things, people, animals, etc. A sample question is shown in Fig. 7. Participants are shown a picture of a pot and two stacked cups, and asked to write text to fill in the balloons. Usually, the scene of pouring hot water or tea from a pot into a cup is assumed. However, the participants are expected to give an answer that goes beyond such a general idea. The last three questions require the participants to invent a new product or service by selecting two or more words from the six word groups given in the question.

3.3. Results and discussion

An analysis of participants' answers clarified two problems. The first was that the load on the participants was much higher than expected. Table 3 lists the time taken to solve all the questions and the impressions obtained as the test was conducted.

As seen in Table 3, more than half of the participants took more than 120 minutes to answer the questions. Some of the participants' comments were: "There were so many questions, so it was hard to stay focused"; "I was tired because there were so many questions"; and "Too long. Please split it up." The second problem was that most questions were descriptive, and answers varied widely, making it difficult to set evaluation standards to ensure reliability among raters. Sample answers for lateral thinking questions are shown in Fig. 8. Both answers are comical dialogue that makes the audience laugh: Japanese Manzai, a two-person comedy act. They are very funny conversations, but it is quite difficult to know how to evaluate them as answers for the creativity test. Questions for the next survey, therefore, had to overcome these issues.

The TTMC Test is a mixed assessment comprising quantitative and qualitative measures. Previous measurements of creativity were consensus-based evaluations by raters, which implies that creativity is inherently at least partly subjective. However, in the TTMC Test, a logical thinking item has a correct answer and can be evaluated mechanically and objectively. For critical thinking and lateral thinking, consensus evaluation by raters is necessary. The TTMC Test was developed through an experimental study designed to test the efficacy of a creativity measurement that relies on both quantitative and qualitative measures.

4. Study 2: Prototype of the Tripartite Thinking Model of Creativity Test

4.1. Method

4.1.1. Participants

The main survey was conducted in September 2011 as a paper-pencil test. Participants worked in the Tokyo metropolitan area in Japan and came directly to the creativity testing site. In total, 345 people responded to the call. Details of the participants' attributes, such as gender, age, and education, are presented in Table 4. Informed consent was indicated at the time of recruitment.

4.1.2. Test procedure

Two subject experts in personal assessment and one graduate student majoring in creativity developed the questions for the prototype version of the TTMC Test. That includes a set of three tests. First, the logical thinking test uses two figure-based and two verbal questions. In the figure-based questions, participants fill in the blanks with words in logic trees. The aim of this question is to see if the participants can accurately model the given topic. In the preliminary survey, participants were required to draw the entire logic tree by themselves, but in the prototype, they were presented with an unfinished logic tree and were asked to choose the appropriate words to fill in the blanks from among the alternatives. The number of alternatives was larger than the number of blanks so that the correct answer could not be obtained without properly identifying the relationship between the upper and lower levels and between

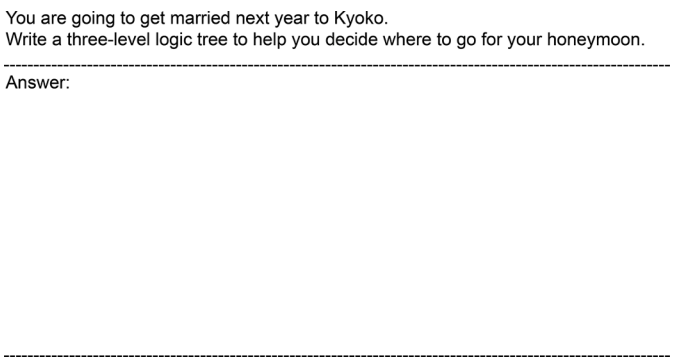


Fig. 5. Sample of logical thinking question.

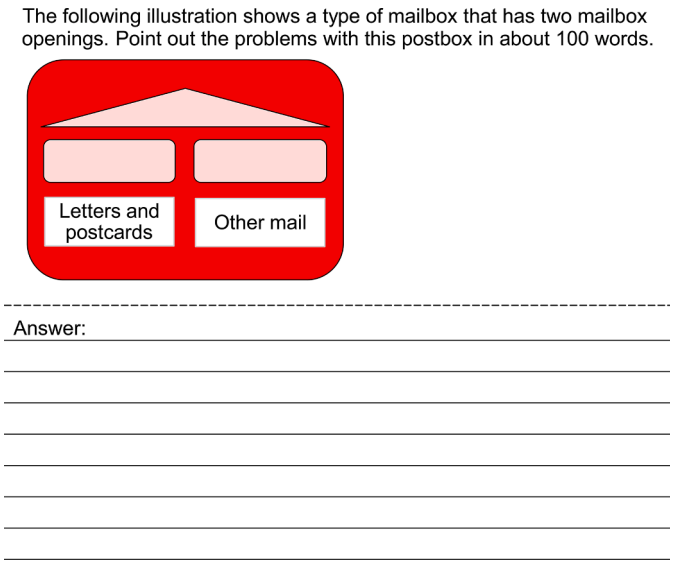


Fig. 6. Sample of critical thinking question (Adapted from Fujisawa, 1999).

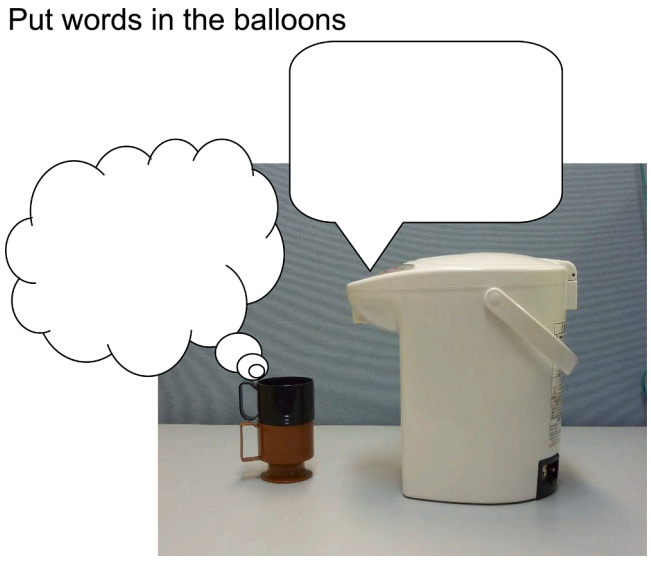


Fig. 7. Sample of lateral thinking question (Adapted from Takahashi & Horikami, 2013).

the left and right levels. In the verbal questions, participants were required to fill in the blanks with proper conjunctions between sentences. The aim of this question was to see if the participants could accurately grasp the relationship between the sentences presented. In the preliminary survey, participants were required to write reasonable conjunctions independently, but in the prototype, they were asked to choose from alternatives. The number of alternatives was larger than the number of blanks so that the correct answer could not be obtained without properly identifying the connection between sentences. Logical thinking questions were scored according to the number of correct answers. The figure-based sample question is shown in Fig. 9. Eight blank boxes and five boxes filled with words beforehand are arranged in the shape of a tree. The participants must fill eight blank boxes with appropriate words from alternatives. If the participants cannot comprehend the relationship between the words while working on the five boxes, they will not succeed in getting the right answers.

All four questions were scored on each box (correct answer = 1; incorrect answer = 0). Each question has a different number of boxes, so scores range from 0 to 8 for I-1 and I-2 (both figure-based), 0 to 3 for I-3 (verbal), and 0 to 5 for I-4 (verbal). The highest, lowest, and mean (*SD*) total scores, respectively, were 8, 2, 6.98 (1.26) for I-1; 8, 5, 7.70 (0.53) for I-2; 3, 0, 1.86 (0.83) for I-3, and 5, 1, 3.93 (1.03) for I-4.

Second, the critical thinking test evaluates the level of evaluating ability using two figure-based and two verbal questions. In the

Table 3
Time each participant required to answer all the questions and their impressions of the tasks.

Participant	Time required to solve all questions	Impressions (summary)
1	180 min.	There were so many questions, so it was hard to stay focused.
2	150 min.	Too many questions, too much work, better to solve on PC.
3	150 min.	It was difficult for me because I'm not very creative.
4	90 min.	I was tired because there were so many questions.
5	180 min.	Questions are simple, but the answers are hard to come by.
6	270 min.	It's been a while since I've taken things seriously, but it's been fun.
7	180 min.	It was very messy.
8	600 min.	Difficult, disgusting.
9	180 min.	Many of the questions were very difficult to answer, and I was tired.
10	300 min.	The questions stimulated creativity and were challenging to answer.
11	2 days	It is difficult to think deeply. I realized my lack of imagination and thinking ability.
12	210 min.	Too long. Please split it up.
13	4 days	Exhausting. I felt strong pressure, like I was being evaluated by a score.
14	120 min.	It was a very hard test.
15	180 min.	I was curious about the background theory.
16	90 min.	It was hard to think for 90 minutes straight.
17	150 min.	Very difficult to solve.
18	80 min.	It was interesting.
19	130 min.	The content is fun. I'm sick of doing the same three questions, it takes too much time, and I can't keep my energy up.

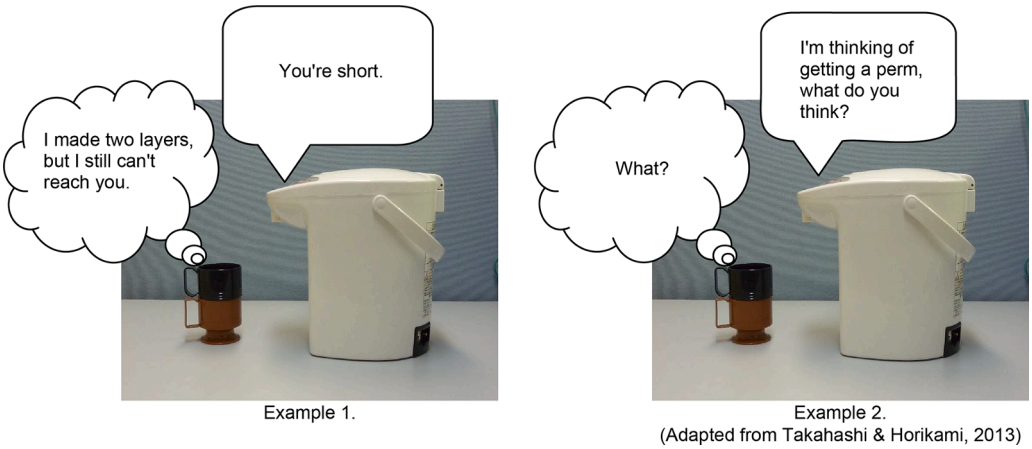


Fig. 8. Examples of participants' answers to a lateral-thinking question.

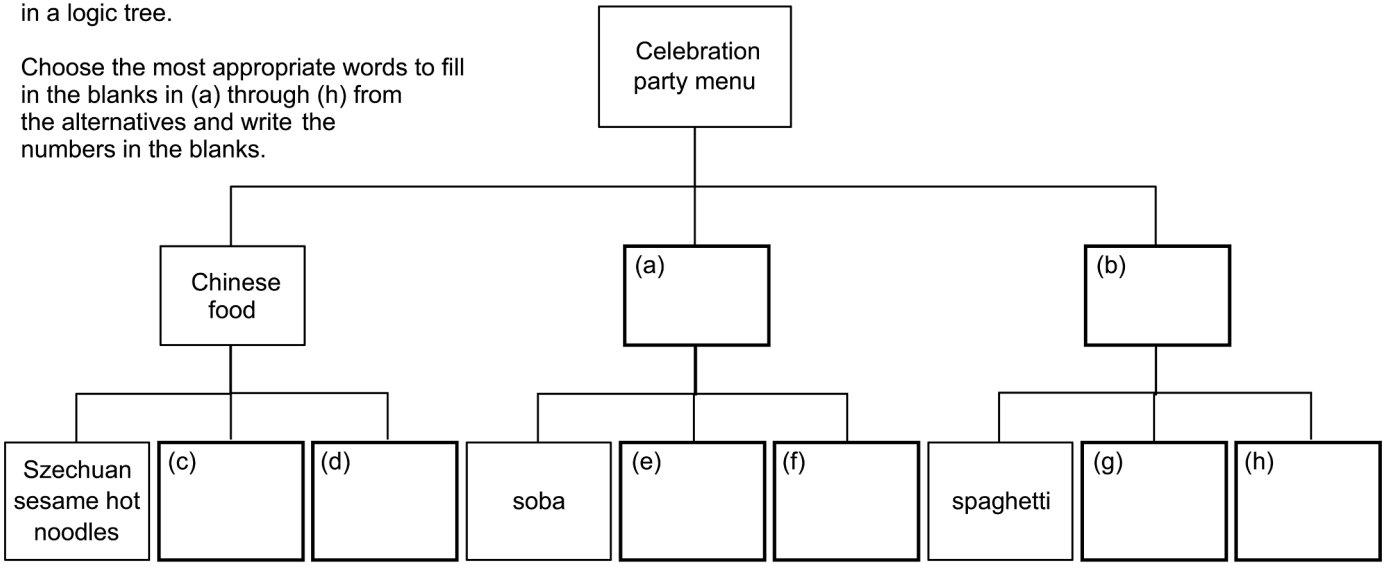
Table 4
Attributes of participants ($N = 345$).

Attribute	Details
Gender	214 men (62.0%) and 131 women (38.0%)
Age	Ranged from 22 to 62 years (average 36.9; $SD = 9.36$); 20s (32.5%), 30s (24.9%), 40s (32.8%), 50s (9.3%), and 60s (0.6%)
Education	Completed postgraduate education (4.6%), college graduates (91%), junior college graduates (1.7%), vocational school graduates (1.7%), and high school graduates (0.9%)
Positions and employment status	In management posts (1.4%), full-time and/or part-time employees (91.0%), public servants (0.9%), self-employed (4.3%), full-time homemakers (1.2%), and unemployed (1.2%)
Average length of service	14.0 years ($SD = 9.18$)

figure-based questions, the participants must identify the symbols and pictures in a figure that are out of place. The aim of this question is to see if participants can appropriately point out problems with visually appealing claims. In the preliminary survey, participants were required to answer in about 100 words, but in the prototype, the method was changed to pointing out three problems of the presented illustration in about three lines of text. For the verbal questions, the participants need to identify the erroneous use of words or incorrect sentences. The aim of this question is to ask whether participants can properly evaluate whether a seemingly flawless claim is true or not. In the preliminary survey, it was not clearly indicated which part of the question should be paid attention to in answering the question, but in the prototype, the subject to be criticized was clearly indicated, and efforts were made to make it easier to answer

Your project has won the President's Award in your company. You are the organizer of the celebration party, and you have organized the party dishes in a logic tree.

Choose the most appropriate words to fill in the blanks in (a) through (h) from the alternatives and write the numbers in the blanks.



Alternatives:
(1) Western cuisine (2) Fried rice (3) Tomatoes (4) Risotto (5) Rice (6) Apricot cake (7) Sushi
(8) Sesame oil (9) Italian cuisine (10) Straw rice cake (11) Tiramisu (12) Japanese cuisine (13) Local cuisine

Fig. 9. Sample of logical thinking question (Q. I-2).

the question. The figure-based sample question is shown in Fig. 10. A post office, hospital, bridge, station, and destination are shown in the figure using an arrow. The participants are unlikely to receive a high score if they fail to identify the problems accurately.

Critical thinking was examined using open-end questions. In this study, the answers were scored by three independent raters: Two subject experts in personal assessment and one graduate student majoring in creativity. The answers were scored with reference to the scoring manual. Based on the scoring manual, the sample question in Fig. 10 is graded on a scale of zero to three. No answer is given = 0; some answer given = 1; the problem is specifically pointed out = 2, the essential problem is pointed out = 3. For example, an answer that merely points out a flaw in the map, such as "There are no directions to the store" = 1. "There are no directions, so I don't know which side of the station to go to," = 2 (because it points out the expected result of the map's flaw). Answers pointing out that the original purpose of the map cannot be fulfilled, such as "This map does not show the way to the store, so cannot reach the store" = 3. (Other sample answers are shown in Appendix A.) Each of the four questions has three answer lines; each is scored from 0–3 points. Thus, the total score for each question ranges from 0–9 points.

The reliability was examined using the inter-rater agreement. Details are shown in Table 5. The average inter-rater reliability for the total score was .89.

The sum of the three raters' scores was used as the critical thinking score. The highest, lowest, and mean (*SD*) scores, respectively, were 27, 0, 9.10 (5.43) for II-1; 21, 0, 7.98 (4.49) for II-2; 22, 0, 10.07 (4 .21) for II-3; and II-4 was 26, 6, 12.99 (4.09). Since the score range was large, from 0 to 27 points, the distribution of each score varied, making it difficult to ensure normality. By examining various class ranges, we found we could approach a more gentle normal distribution by adjusting the class range to 0 to 6 points for all four questions. As a result, the highest, lowest, and mean (*SD*) scores, respectively, were 6, 0, 3.04 (1.67) for II-1; 6, 0, 2.78 (1.47) for II-2; 6, 0, 3.46 (1.49) for II-3; and 6, 0, 2.19 (1.05) for II-4.

Third, the lateral thinking test measures the level of idiosyncratic thinking, novel ideas, humor, and remote association of unrelated words using four verbal questions and two figure-based questions. In the first type of verbal question, the participants are required to provide solutions for fictitious problems. The aim of this question is to see how flexible participants can be in finding a solution to a problem situation that is not likely to have an easy solution, in other words, to see if participants can change the pattern. In the second set, the participants must consider new products and services combining the designated unrelated words. The aim of this question is to see how free participants are to think beyond the common sense ideas they have when seeing people, objects, animals, etc., in

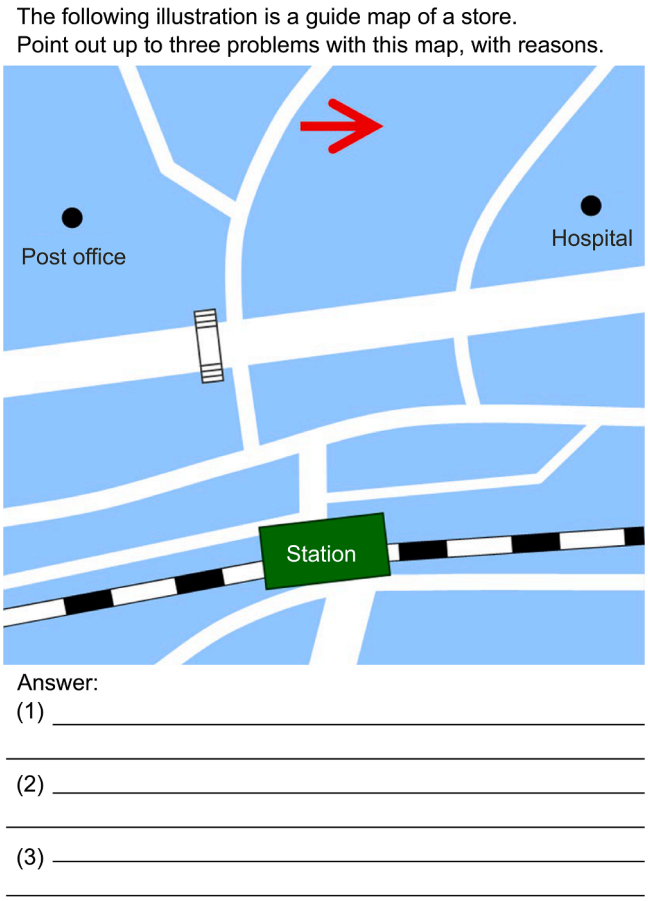


Fig. 10. Sample of critical thinking question (Q. II-4).

photographs and illustrations, in other words, to see if they can change visual patterns. In the two types of verbal questions, in the preliminary survey, participants were required to answer in about 100 words, but in the prototype, the answer column was changed to just five lines of ruled text. In the figure-based questions, the participants are required to provide balloon text and titles for cartoons. The aim of this question is to see how much freedom participants have in their thinking by changing the pattern of the word beyond its common usage. The difference from the preliminary survey was that there was one less balloon and more tasks to think of a title instead. In the preliminary survey, the presence of two balloons led to many answers that were like comic dialogue. Even though they were interesting, it was questionable if they could be evaluated as having lateral ideas. Therefore, in the prototype, the task was to reduce the number of balloons to one and give a title to the picture presented in the question so that the participants could understand how the picture was perceived. The figure-based sample question is shown in Fig. 11. There is a cup, clock, pen, and a notebook on the desk. The cup has a balloon that can be used to describe something. The participants are required to fill the balloon with appropriate words and provide a title for the picture. The participants can receive a high score if they arrive at unique and smart answers.

Lateral thinking is also examined using open-end questions. The same raters independently scored the answers with reference to the scoring manual. The sample question in Fig. 11 is graded on a scale of 0–3 points: No answer written = 0; basic answers are given = 1; answers that deviate slightly from the common sense approach to the situation = 2; answers that deviate significantly from the common sense approach to the problem (i.e., not many people would or could think this way) = 3. For example, the title of "Coffee Break" with a balloon text "Hot Coffee" = 1 point one because it merely describes the photo; "The Melancholy of the Coffee Cup" title with balloon text "I wish I were a little more rounded, too" = 2 because it seems unlikely; the title "Evil Cup" with balloon text "If I cover the clock, no one will be able to see the clock" = 3 points, as it is a unique idea. All six questions are scored in the range of 0–3 points. (Other sample answers are shown in Appendix B.)

The reliability was examined using the inter-rater agreement. Details are shown in Table 6. The results of III-5 and III-6 show low correlation. These two questions were about devising a new product or service using the presented words and phrases. The raters were divided in their judgments about what kind of answer would be highly evaluated as a new product or service. Overall, the score for the inter-rater agreement was as moderate as .60.

The sum of the three raters' scores was used as the lateral thinking score. The highest, lowest, and mean (*SD*) scores,respectively, were 9, 3, 5.06 (2.04) for III-1; 9, 3, 5.84 (0.67) for III-2; 9, 3, 3.92 (1.49) for III-3; 9, 3, 4.19 (1.53) for III-4; 9, 3, 3.39 (0.87) for III-5; and III-6 was 9, 0, 3.44(1.03).

4.1.3. Discriminant validity

The ATTA (Goff & Torrance, 2002) was employed to examine the discriminant validity. Although the ATTA (adult version of TTCT) is designed to deal with divergent thinking exclusively, this creativity measure has been widely used. For the ATTA, answers are rated independently by two personal assessment experts, according to Goff and Torrance (2002). The inter-rater correlation coefficient between the two raters was as high as .93.

4.2. Results

This study is not designed to test a hypothesis, and the TTMC is designed to be accepted or rejected based on the goodness of fit between the model and the data. Therefore, in this section, construct validity will be checked from the results of the main survey by using confirmatory factor analysis to test the goodness of fit with TTMC. In addition, discriminant validity will be checked by covariance structure analysis.

4.2.1. Construct validity

Construct validity was examined through CFA. When developing a new scale, EFA may first be conducted to extract common factors, and then CFA may be conducted again. In this study, however, the constructs were determined first, and observable variables were set. Therefore, the degree of fit between the construct and the observed variables is checked from the beginning by CFA without using EFA.

As seen in Fig. 12, the hierarchical creativity model assumes the latent construct of creativity at the highest degree with three subdomains of logical thinking (LOT), critical thinking (CRT), and lateral thinking (LAT). The results of the CFA (see Fig. 12 and Table 7) found that all indices suggested a good model fit: GFI = .967, AGFI = .953, CFI = .954, RMSEA = .022, and $\chi^2(74) = 86.10$, $p > .05$.

Table 5
Inter-rater reliability of critical thinking test (correlation coefficients of the three raters).

Between raters	Verbal-based		Figure-based	
	II-1	II-2	II-3	II-4
A-B	.90**	.86**	.86**	.86**
A-C	.92**	.90**	.90**	.90**
B-C	.93**	.91**	.90**	.86**
Mean	.92	.89	.89	.87

** $p < .01$.

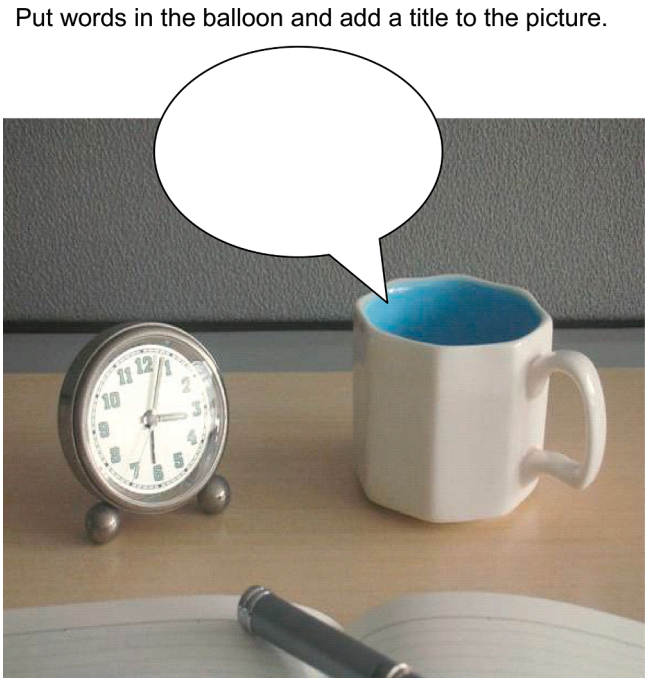


Fig. 11. Sample of lateral thinking question (Q. III-3).

Table 6
Inter-rater reliability of lateral thinking test (correlation coefficients of the three raters).

Between raters	Verbal-based 1		Figure-based		Verbal-based 2	
	III-1	III-2	III-3	III-4	III-5	III-6
A-C	.87**	.68**	.79**	.62**	.42**	.49**
A-D	.86**	.62**	.72**	.64**	.44**	.55**
C-D	.81**	.39**	.70**	.62**	.26**	.40**
Mean	.85	.56	.74	.63	.37	.48

** $p < .01$.

4.2.2. Discriminant validity

Discriminant validity was examined using the covariance structure analysis. As shown in Fig. 13, the latent variable, creativity, was regressed onto the observed variable, ATTA. The results indicated that this model examining the criterion-related validity is feasible: GFI = .964, AGFI = .950, CFI = .952, RMSEA = .021, and $\chi^2(87) = 100.197$, $p > .05$. However, as shown in Table 8, the correlation between the ATTA and the creativity measure comprising three thinking tests showed a moderately low correlation (.27). This means that the theoretical constructs covered by the TTMC Test and ATTA are different.

5. Discussion

This study examined how previous research views creativity by reviewing the construct of creativity addressed in the creativity measures included in Plucker et al. (2021). The results showed that most creativity measures did not clarify the construct of creativity; exceptions include divergent thinking (Guilford, 1967; Torrance, 2008a, 2008b, etc.), SSCM (Hu & Adey, 2002), and CPSS (Besemer & O'Quin, 1999). However, there is a challenge that divergent thinking itself is not the same as creativity. The SSCM proposes a three-dimensional model of creativity, but the construct is not fully explained. The CPSS measures creativity using CPAM (Besemer & Treffinger, 1981) as a construct; however, it evaluates the product as a proxy for creativity and does not directly measure a person's inner creativity.

Therefore, the first step in this study was to derive the construct of creativity theoretically. We narrowed down the people and situations that demonstrate creativity according to Maslow (1959) and De Bono (1992). Also, following Rhodes' (1961) 4Ps, we narrowed down the aspects of the process. Based on arguments that creativity is closely related to creative problem solving (e.g., Amabile, 1996), we examined the thinking processes exhibited in creative problem solving (e.g., Bransford & Stein, 1993). As a result, a construct of creativity was developed: the TTMC, which consists of logical thinking based on the concept of modeling (e.g., Nonaka & Konno, 2003; Sato, 2009); critical thinking based on Glaser (1941), Ennis (1962, 1987), and Zechmeister and Johnson (1991); and

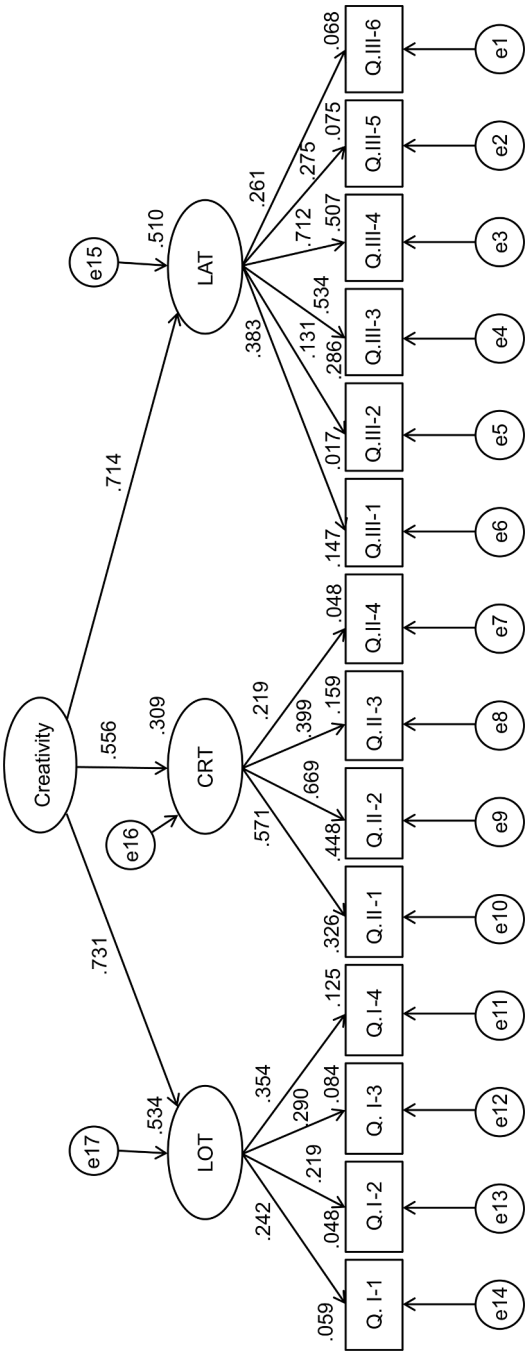


Fig. 12. Construct validity of the tripartite creative thinking test: standardized estimates

Table 7
Regression Weights.

			Unstandardized estimate	*SE*	*CR*	*p*	Standardized estimate
LOT	←	Creativity	1.000				.731
CRT	←	Creativity	0.482	0.231	2.084	.037	.556
LAT	←	Creativity	0.722	0.349	2.070	.038	.714
Q. I-1	←	LOT	0.834	0.388	2.147	.032	.242
Q. I-2	←	LOT	0.316	0.156	2.023	.043	.219
Q. I-3	←	LOT	0.660	0.281	2.353	.019	.290
Q. I-4	←	LOT	1.000				.354
Q. II-1	←	CRT	4.137	1.365	3.030	.002	.571
Q. II-2	←	CRT	4.269	1.415	3.018	.003	.669
Q. II-3	←	CRT	2.586	0.902	2.867	.004	.399
Q. II-4	←	CRT	1.000				.219
Q. III-1	←	LAT	2.906	0.869	3.344	.000	.383
Q. III-2	←	LAT	0.327	0.184	1.777	.076	.131
Q. III-3	←	LAT	2.956	0.813	3.636	.000	.534
Q. III-4	←	LAT	4.061	1.108	3.666	.000	.712
Q. III-5	←	LAT	0.885	0.303	2.916	.004	.275
Q. III-6	←	LAT	1.000				.261

lateral thinking based on De Bono (1967, 1970, 1971, 1990, 1992). This development of the creative process has relied solely on the divergent thinking represented by TTCT.

The TTMC derived in this study does not directly represent the dependency and sequential relationships among the three modes of thinking. It also does not directly explain how the high and low scores of the three modes of thinking affect creativity. Nevertheless, the construct validity has been verified by placing the construct of creativity on top of the three modes of thinking, so it could be said that the TTMC does encompass such things to some extent. However, if, for example, it were possible to assess all three modes of thinking simultaneously and comprehensively with a single question, it might be possible to make the TTMC more robust. It is not clear if the TTMC is the best answer, but it would have provided some ideas on how to build the construct of creativity. Therefore, it can be said that the first purpose of this study, to construct a new theoretical concept of creativity, was almost achieved.

The logical thinking tests, which are components of the TTMC Test, can be evaluated objectively. However, critical and lateral thinking tests require consensus by raters. In previous studies, creativity has been assessed as having a subjective aspect; however, the TTMC Test has an experimental aspect for testing the efficacy of a creativity measurement that relies on both quantitative and qualitative measures.

In reliability testing, inter-rater reliability was high for critical thinking questions; however, there were some low correlations for the lateral thinking questions. Evaluating answers that are different from conventional and ideas, such as lateral thinking, proves difficult even for experts. Thus, it is necessary to set questions that allow for a more objective evaluation.

For construct validity, in many previous studies, data was obtained by identifying as many observable variables as possible that seemed creative, common factors were extracted by EFA, and then construct validity was verified by CFA. However, in this study, the construct was theoretically derived first, and then the construct validity was confirmed using data. If there is no error in the process used to derive the construct, and the fit between the construct and the data is not good, the method of obtaining data on the observed variables should be checked rather than the construct. It would be an example of developing construct and measure in a confirmatory rather than exploratory manner.

According to the result of construct validity test of the TTMC Test, the overall fit of the model was good; however, some factor loadings of individual observable variables are low. As shown in Table 7, all four-factor loadings are low in LOT. The standard deviations were 1.26, 0.53, 0.83, and 1.03, which may be because most participants had high scores, and there was not much variation in the scoring results. The other variables with low factor loadings also had standard deviation values around 1, indicating low variability in the scoring results. There was room for improvement in the setting of the questions with higher variance.

An examination of the discriminant validity by covariance structure analysis showed that the TTMC Test was not correlated highly with the ATTA. Although the TTCT/ATTA measures divergent thinking, it is only a part of the realm of creativity (Plucker et al., 2021; Runco, 1993). Because the TTMC Test covers other types of thinking, it may simply mean that the TTMC Test and TTCT/ATTA measure different constructs of creativity.

Based on the above results, it could be said that the second objective of this study, to develop a creativity measurement test for TTMC, has been achieved to some extent from an initial attempt, although some issues remain to be addressed.

6. Limitations and Directions for Future Research

There are also further characteristics of this study that could be viewed as limitations. For example, the TTMC Test is still nascent compared to other full-fledged test inventories. So far, only four questions for logical and critical thinking and six questions for lateral thinking have been implemented. More questions are necessary to draw a full range of measurements for diverse creativity domains.

For the evaluating process, in the critical and the lateral thinking tests, the answers were manually graded by three raters. It took around six days for each rater to mark the answers of 345 participants. Therefore, it will be necessary to consider questions and

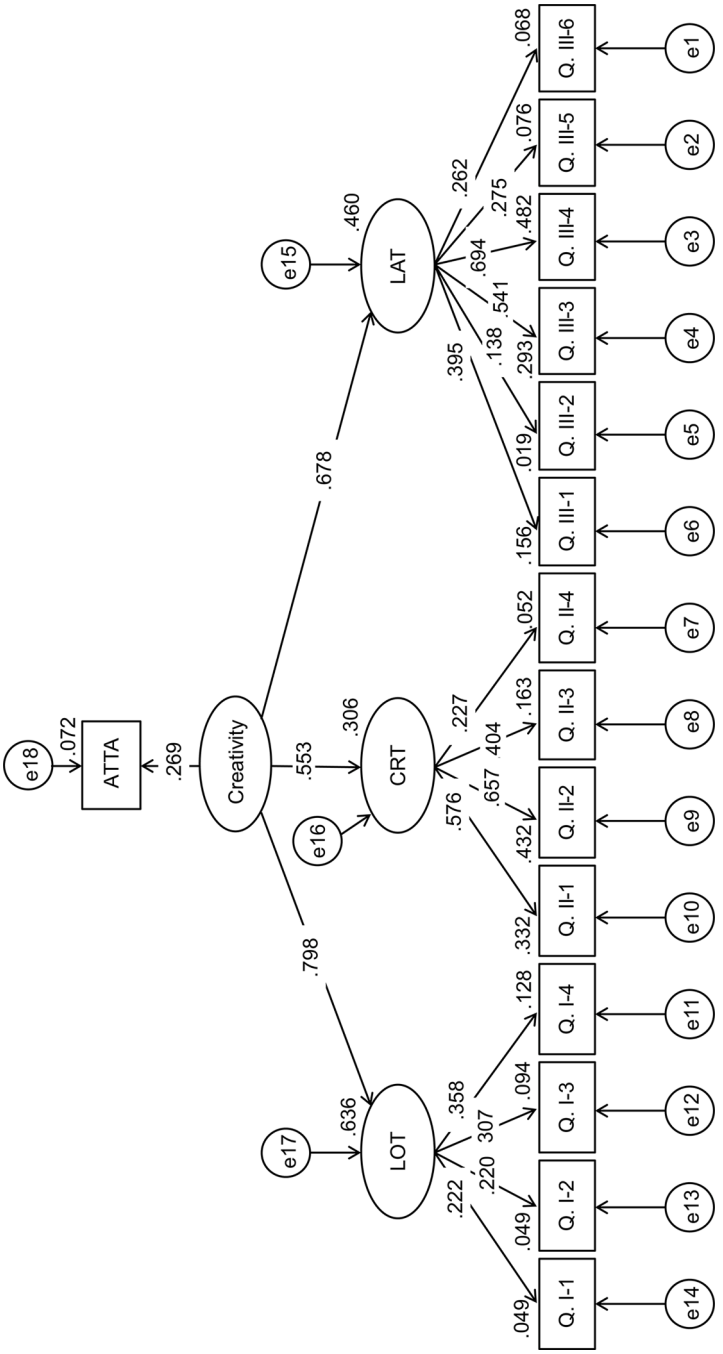


Fig. 13. Discriminant validity of the tripartite creative thinking test: standardized estimates

Table 8
Regression weights

			Unstandardized estimate	*SE*	*CR*	*p*	Standardized estimate
ATTA	←	Creativity	20.384	8.308	2.454	.014	.269
LOT	←	Creativity	1.000				.798
CRT	←	Creativity	0.451	0.205	2.197	.028	.553
LAT	←	Creativity	0.622	0.270	2.299	.022	.678
Q. I-1	←	LOT	0.755	0.351	2.154	.031	.222
Q. I-2	←	LOT	0.314	0.147	2.146	.032	.220
Q. I-3	←	LOT	0.690	0.268	2.578	.010	.307
Q. I-4	←	LOT	1.000				.358
Q. II-1	←	CRT	4.019	1.286	3.125	.002	.576
Q. II-2	←	CRT	4.033	1.294	3.117	.002	.657
Q. II-3	←	CRT	2.520	0.853	2.954	.003	.404
Q. II-4	←	CRT	1.000				.227
Q. III-1	←	LAT	2.990	0.889	3.364	.000	.395
Q. III-2	←	LAT	0.344	0.186	1.844	.065	.138
Q. III-3	←	LAT	2.984	0.822	3.629	.000	.541
Q. III-4	←	LAT	3.947	1.077	3.666	.000	.694
Q. III-5	←	LAT	0.884	0.304	2.906	.004	.275
Q. III-6	←	LAT	1.000				.262

evaluation criteria that are easier to grade. Or, as the development of artificial intelligence technologies such as natural language processing and machine learning continues, it is desirable to develop an automatic grading system that utilizes such methods. Automatic scoring of lateral thinking questions has been attempted by supervised (Horikami & Takahashi, 2018a) and unsupervised machine learning (Horikami & Takahashi, 2018b), but has not yet reached a stage where it can be put to practical use.

The TTMC Test is an experimental measure with both quantitative and qualitative aspects; the overall goodness of fit of the construct validity and discriminant validity was good; hence, this experiment was relatively successful. However, some low values for inter-rater reliability and factor loadings indicate that a great deal of ingenuity is still needed in setting the questions. Thus, there is still much room for improvement in the TTMC Test, and further research is necessary to address the many challenges that must be resolved before we can declare the new creativity test to be practical and useful as a corporate management tool.

More importantly, how can we foster creativity? To utilize research results in the real world of practice, it is necessary to have both the methods to foster creativity and the scales to measure it. This question is also of great interest to us, but is beyond the scope of this study. It will be the subject of our future research.

Even though the TTMC was developed with reference to the thinking process of creative problem solving, the derived construct is a simple model of the thinking processes of creativity. It may apply in situations where non-problem-solving creativity is required. For this purpose, more extensive validation is needed by obtaining data on various cases. Although further research is required, the potential for future development is promising.

Data availability statement

We cannot make our data fully available because the statement of informed consent signed by the participants promised that their individual data would not be released.

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CRediT authorship contribution statement

Akira Horikami: Conceptualization, Investigation, Formal analysis, Writing – original draft. **Kiyoshi Takahashi:** Supervision, Writing – review & editing.

Declaration of interest

None.

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Appendix A

Sample answers to the critical thinking test for Fig. 10 (Q. II-4).

Participants' answers	Score		
	Rater A	Rater B	Rater C
I don't know what the red arrows indicate (there is no explanation for the arrows).	1	1	1
I don't know which exit to take from Station A.	1	1	1
The direction is not indicated. When I get off at a station, I can't decide which ticket gate to exit from.	2	2	2
The name of the exit of station A is not written. If I take the opposite exit, I will get lost.	2	2	2
The location of the store is ambiguous, so it is difficult to know its actual location and distance from the station.	3	3	3
Since the route to the store from Station A is not written, it is inappropriate as a guide map.	3	3	3
There is insufficient information about the distance from the station (~m or ○ minutes walk). The route from the station should be marked with arrows.	1	2	1
The location of the store is unclear, and it is not clear whether I can enter from the post office side or the hospital side.	2	1	2
Distance to the store is unknown due to lack of scale.	3	2	2
There are too few landmarks on the map, and there is a risk of getting lost.	3	3	2

Note: Since the original answers were written in Japanese, we have selected some answers that could be relatively easy for English-speaking people to understand.

Appendix B

Sample answers to the lateral thinking test for Fig. 11 (Q. III-3).

Participants' answers		Score		
Title	Text in balloon	Rater A	Rater B	Rater C
Afternoon Tea Time	I guess it's time for me to go.	1	1	1
Snack Time	It's past three o'clock, so it's time for a snack.	1	1	1
Tea Time	It always gets busy at 3:00...	2	2	2
At the Office on Holiday	I usually get my coffee at this time of day...	2	2	2
Mission Impossible: Land of the Giants	Hey, can someone put some rope in this coffee cup? If I don't do it soon, the night will end.	3	3	3
Lie	It's two o'clock.	3	3	3
The Anxiety of Cooled Coffee.	Wake up, you idiot. It's almost morning. The deadline for the manuscript is 10:00.	1	2	1
Studying for a Test at Night	You said you'd try your best not to sleep today...	2	2	1
Surprising Rest Time	Before he comes back, I'll make sure the clock is running.	3	3	2
Daily Question	Speaking of which, what time does that alarm go off, 6:xx?	2	3	2

Note: Since the original answers were written in Japanese, we have selected some answers that could be relatively easy for English-speaking people to understand.

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