MTCA

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Despite decades of extensive research on creativity, the field still combats psychometric problems when measuring individual differences in creative ability and people's potential to achieve real-world outcomes that are both original and useful. We think these seemingly technical issues have a conceptual origin. We therefore propose a minimal theory of creative ability (MTCA) to create a consistent conceptual theory to guide investigations of individual differences in creative ability.

Keywords: creativity measurement ; creative potential ; divergent thinking ; intelligence ; expertise

1. Positioning the MTCA

The MTCA is a theory based in differential psychology, the field Cronbach (1957) describes as the psychology of individual differences. The aim of differential psychology is to determine the nature, magnitude, causes, and consequences of psychological differences between individuals in the general population. So, with the MTCA we address how and why people differ in real-world creativity, where the major challenge is measuring creative ability. Please note that we focus on creative ability, not the creative process (for different accounts of the creative process see e.g., Gabora 2017; Hélie and Sun 2010; Kozbelt et al. 2010; Nijstad and Stroebe 2006; Schmidhuber 2010; for a thorough analysis of the study of individual differences versus processes see Cronbach 1957). So, the MTCA does not answer questions, such as, "How does the creative act take place?" and "What happens in the brain during creative problem solving?". Instead, we focus on questions such as "What are the components of creative ability?"; "How can creative ability be measured?"; "Are individual differences in creative ability stable over time?"; and "Can creative ability be trained?". We show that the MTCA provides clear answers to each of these questions about creative ability.

Because the MTCA is concerned with individual differences in creative ability, it is positioned in the Person perspective of creativity. The Person perspective represents one of the four general approaches to creativity research and focuses on which characteristics make a person creative (Rhodes 1961). With MTCA, we argue that intelligence and expertise are the essential person characteristics that distinguish between people scoring high or low on creative ability. The MTCA is also concerned with the Product perspective of creativity, focusing on the extent to which ideas, acts, and output are judged, often by relevant experts and stakeholders, to be creative (Amabile 1982; Montag et al. 2012; Simonton 2003c). Real-world creative products or outcomes are the most important criteria that the MTCA strives to predict. These creative outcomes may range from personal and everyday creative outcomes to eminent creative contributions (Boden 2004). For instance, they may refer to a sudden insight in how to solve a Sudoku (mini-c creativity); a new vegetable dish that your toddler enjoys eating (little-c creativity); a newly developed creativity test (Pro-c creativity); or a renowned paradigm-changing scientific theory (Big-C creativity). As such the MTCA addresses creative ability and potential at all levels, from mini-c to Big-C (Kaufman and Beghetto 2009).

The Process perspective, concerned with the cognitive processes that take place when someone is being creative, is not central to the MTCA. The MTCA only addresses research positioned in the Process perspective inasmuch as it says something about creative abilities. For example, we argue that many cognitive processes are involved in being creative and therefore cognitive ability is related to creative ability (e.g., Kozbelt et al. 2010; Simonton 2003b; Mumford and McIntosh 2017). Similarly, we only address the Press perspective, which investigates the circumstances or states that influence the expression of creative ability, to the extent that it informs us about creative abilities. For instance, environmental stressors, such as noise and cognitive load, make it harder for people to be creative because they hinder the execution of cognitive abilities (Byron et al. 2010; De Dreu et al. 2012). So, the MTCA does not deny that creative processes exist (it actually assumes their existence), nor that there are important situational constraints and triggers that influence how creativity emerges. However, the MTCA simply is not a theory about the creative process or environment, but about individual differences in creative ability (cf. Cronbach 1957; see e.g., [1] for a model in which both individuals and environmental factors interact to express creative achievements).

The MTCA is based on two key assumptions. The first assumption is that in order to be creative we use a wide variety of cognitive functions: functions that are generally assessed in intelligence tests. The second assumption is that creativity relies on the novel combination of existing knowledge and skills, i.e., expertise. Combined, these assumptions lay the groundwork for the MTCA, where intelligence and expertise are essential to understanding why people differ in creative ability. Below, we explore these assumptions further and conclude with a quasi formula for a minimal theory of creative ability.

Assumption 1.

Creative ability requires many different cognitive abilities.

The MTCA is based on the common assumption that we use a wide variety of our cognitive abilities to be creative (and probably tap all our cognitive functions across different tasks and settings). Whatever the challenge is, we use many cognitive abilities, such as those assessed in intelligence tests. For instance, we may use our perceptual abilities, conduct convergent and divergent thinking, search our memory for analogies, make use of our knowledge base, focus our attention, acquire new knowledge, etc. (e.g., Amabile and Pratt 2016; Beaty et al. 2014; Benedek et al. 2014; Kuncel et al. 2004; Newell and Simon 1972; Nijstad and Stroebe 2006; Sternberg et al. 2019).

We consider this assumption rather uncontroversial because most theories of creativity are consistent—or at least not inconsistent—with the idea that many cognitive functions are needed to be creative. For example, process theories of creativity are consistent when they describe the creative process in terms of consecutive stages (e.g., problem identification, idea generation, idea evaluation; see e.g., Basadur et al. 1982; Mumford and McIntosh 2017; Perry-Smith and Mannucci 2017; Wallas 1926) or some sort of cycle (e.g., including repetition and recursion) where different executive functions play a role (for overview see Kaufman and Glaveanu 2019; Kozbelt et al. 2010). This also applies to Amabile's (1982) componential model and other componential theories that incorporate several creativity-relevant cognitive processes (e.g., breaking cognitive and perceptual sets, remembering accurately). We think typical cognitive process theories such as the Geneplore model (Finke et al. 1992) or Hélie and Sun's (2010) Explicit–Implicit Interaction theory are also consistent with this assumption as they involve many cognitive functions. For instance, according to the Geneplore (generate–explore) model, people first retrieve existing elements from memory, form simple associations among these elements, and integrate, and transform them. The new ideas that result from these generative processes are then explored for their implications, checked against criteria and constraints and, if needed, refined (Finke et al. 1992).

Furthermore, theories on creativity that stress the importance of one cognitive function, such as associative thinking (Mednick 1962) or incubation (Sio and Ormerod 2009; Wallas 1926), are not inconsistent with our assumption as long as they acknowledge that other cognitive processes play a role in creativity as well. Inconsistency arises when a theory assumes that only one specific function is essential. This occurs when creative ability is reduced to divergent thinking ability only, for instance, as some psychometric theories of creativity propose (see Kozbelt et al. 2010).

Assumption 2.

Creative ability requires expertise.

We further assume that people apply their cognitive functions to analyze, combine, and integrate existing knowledge and skills to be creative (Simonton 2003b). This is why being creative in any domain also requires expertise in the domain at hand. Thus, the MTCA is based on the assumption that creativity always requires expertise ([2] 2011b; [3] 2011b; Plucker and Beghetto 2004). As with the "many cognitive abilities" assumption, we are certainly not the first, nor the only researchers to make this claim. A number of creativity theories recognize that creativity manifests in specific domains. For example, Baer and Kaufman (2005) use an amusement park metaphor to describe how domain specific creative abilities (e.g., writing sonnets) are related to broader and broader abilities (e.g., poetry writing, creative writing), where each level has its own requirements in terms of domain specific knowledge (e.g., word meanings) and skills (e.g., spelling, grammar, rhyming). Domain specificity also follows from Amabile's (1982) componential model, where people use domain relevant skills to be creative and their motivation to be creative may be very specific to tasks within particular domains. Another example stems from Darwinian creativity models that argue that creativity involves a process of random generation and selective retention and elaboration of ideas (e.g., Campbell 1960; Simonton 1999b; but see Gabora 2017 for an alternative evolutionary model). According to these models, people's brains produce (quasi)random variations of existing ideas that are part of a creator's knowledge base, and the greater the knowledge base, the more potential new combinations that are truly creative are possible.

Other theories that discuss the domain specificity of creative output are, for example, Boden's (2004) H-creativity or Big-C creativity (Kaufman and Beghetto 2009), which typically emerges by applying domain specific knowledge acquired over at least a decade. This is supported by archival evidence (e.g., Simonton 1991). For instance, Hayes (1989) discovered that for eminent composers at least 8 years of musical study were required before they wrote a masterwork, and the vast majority required at least 10 years. From the perspective of expertise development, practicing skills, engaging in activities, and enriching the knowledge base in a particular domain provide the necessary building blocks for creative work in that domain (Beghetto and Kaufman 2007; Ericsson et al. 1993; Simonton 2008; [4] 2018).

Although Big-C creative achievements in a particular field often require 10 years of expertise development in that field, there are notable exceptions. For instance, break-through inventions may open up new territory for accelerated discovery, sometimes resulting in entirely new domains. For instance, celestial objects and phenomena were suddenly observable with Galileo's refinement of the telescope thereby explosively advancing the field of astronomy (Simonton 2012); and because microscopic organisms and cells could suddenly be explored with Van Leeuwenhoek's single-lensed microscope, an entirely new domain, microbiology, came into being (Simonton 2012). However, even then, people build on their expertise (e.g., knowledge, scientific observation and reporting skills) to make discoveries and build and advance a domain.

2. A Quasi Formula for the MTCA

In sum, the MTCA assumes that being creative requires a variety of cognitive functions similar to those generally assessed in intelligence tests and expertise relevant to the domain at hand. Although there may be many factors that predict real-world creativity, we argue that only intelligence and expertise are essential for explaining individual differences in real-world creativity. The minimal theory of creative ability (MTCA) can be expressed by the following quasi formula:

C (Creativity) = I (Intelligence) × E (Expertise).

Thus, for a highly intelligent person without any expertise (in, say, culinary arts), C would be zero (in the domain of culinary arts). Furthermore, a resourceful and inventive craftsman without any formal education, perhaps even unable to read, may come up with creative solutions for problems in his or her area of expertise. Yet, creativity always requires some level of intelligent processing. The MTCA simply claims that whenever we are confronted with a creative task, we use a wide variety of cognitive abilities (e.g., our memory, our ability to reason by analogy, our visual–spatial skills, our metacognitive capacities, etc.) in combination with relevant expertise (e.g., experience with carpentry techniques, paint textures, conducting scientific experiments, etc.) to be creative. That is still a lot, but that is all there is. We argue that there is no special creative talent or faculty, nor is there a specialized (brain) area for being creative (e.g., Dietrich and Kanso 2010).

Just as with other theories, we suggest that creative ability constitutes a multiplicative relation of multiple factors. For instance, Eysenck (1995) defined creativity as a product of personality, environmental variables and cognitive ability, including intelligence and knowledge, whereas Simonton (1999a) and Jauk et al. (2013) used the multiplicative relation between multiple factors to explain skewed distributions in creative achievement. In the case of MTCA, the multiplicative relationship is limited to intelligence and expertise. The multiplication sign indicates that I and E both are necessary for creativity, but can also compensate for each other.

3. Phenomena Consistent with the MTCA

As a parsimonious framework of creative ability, the MTCA is consistent with a number of recurring phenomena in creativity research.

Phenomenon 1.

Creativity is related to intelligence.

Creativity research is fraught with evidence that intelligence is related to performance on commonly used tests of creative ability, such as divergent thinking, as well as to creative achievements (De Dreu et al. 2012; Jauk et al. 2013; Silvia 2015; Sternberg et al. 2019; see Sternberg and O'Hara 2000 for an in depth discussion of the relationship between intelligence and creativity.). For instance, Silvia (2015) estimates the correlation between IQ and creative ability as measured with divergent thinking tests to be $r \approx 0.50$. In addition, tests of intelligence and executive functioning are robust predictors of creative eminence and actual creative achievements (Jauk et al. 2013; Karwowski et al. 2016; Silvia 2015; Simonton

2003a). The idea that cognitive abilities are strongly related is not new. Different subtests of IQ tests show a positive manifold of intercorrelations and different composite scores (factor analytic or sum scores) correlate very strongly (van der Maas et al. 2006). According to this perspective, cognitive abilities that in some creativity theories are considered special for creativity, such as divergent thinking, are simply part of a bigger construct: intelligence1. Although divergent thinking tests are not often part of IQ tests, we see no reason why valid divergent thinking tests with good test–retest reliability (e.g., with more items and automated scoring) shouldn't be included. In fact, there have been attempts to make this happen (Kaufman et al. 2011; Süb and Beauducel 2005). We note that specific creative achievements may require a different balance of cognitive functions (Murphy 2017). Writing a poem requires more language abilities than solving a chess puzzle. However, because cognitive abilities are strongly correlated (van der Maas et al. 2006), and we use a wide variety of cognitive abilities to analyze, combine, and integrate existing knowledge and skills during creative problem solving, it is hardly surprising that general intelligence tests robustly predict real-world creativity.

Phenomenon 2.

Creative achievement is domain specific.

Most creativity tests correlate weakly among each other, i.e., have low convergent validity. This could partly be due to the low test–retest reliability (i.e., stability) of standardized creativity tests and resulting error variance (Barbot 2019; Cropley 2000). However, an even more important reason follows from the MTCA: creative achievements build on expertise, and because expertise is domain specific, creative achievements are also domain specific. Whatever the challenge, people simply have to work with the knowledge and skills that they have. An experienced sketch artist with good drawing skills may score higher on the figural subset of the Torrance Test of Creative Thinking (TTCT Torrance 2008) than an experienced creative writer, who, in turn, is more likely to score higher on the verbal subset of the TTCT and the Remote Associates Test (Mednick 1963). The MTCA thus also explains why many experts excel in their profession, but fail to find creative solutions for simple tasks in other domains (Kaufman et al. 2010a). More generally, the expertise component of MTCA clarifies the substandard construct validity of existing creative ability tests (cf. Baer 2012; Han 2003). A prime example of poor construct validity is that the figural and verbal components of the popular TTCT correlate < 0.10 ([2] 2011b). Another example is that creativity scores from different domains (e.g., poetry and mathematics) tend not to correlate, or correlate only weakly ([5] 1994b; Runco and Albert 1985; Simonton 2003b).

Domain specificity may also explain the low predictive validity of domain general creativity tests, such as the Alternative Uses Task (AUT Guilford 1967). Performance on such creativity tests generally correlates weakly with objective indicators of overt creative behaviors (Kim 2008; Zeng et al. 2011). For example, in a meta-analysis, Kim (2008) found a correlation of 0.22 between divergent thinking test scores and creative achievement. Note that for IQ, correlations with external criteria such as job success are reported to vary between 0.27 and 0.61 (for reviews see Schmidt and Hunter 1998; Sternberg et al. 2001) and predictive values of IQ as high as 0.81 are reported for educational achievement (Deary et al. 2007).

Phenomenon 3.

Many experts have a few creative achievements; few experts have many.

The distribution of achievements is often highly skewed in the population. For example, Murray (2009) describes this for professional golfers. Numerous players have won one or two tournaments, only four have won >30 tournaments, and then only one player (Jack Nicklaus) has won 71 tournaments (Murray 2009). This distribution is referred to as the Lotka curve, and also applies to creative achievements. This curve was first described by Lotka (1926) as a power law function where many authors produce a few publications, but only a few authors produce many publications (e.g., Simonton 2003c). Lotka's curve has been found to hold for achievements in numerous domains, including chess and music composition (Murray 2009; Simonton 1999c). Many models have been proposed to explain this phenomenon (for overviews see Den Hartigh et al. 2016; Simonton 1999a). Generally, these models invoke some combination of factors, such as latent ability and number of produced outputs. In the MTCA creative ability is a combination of intelligence, which is generally assumed to be normally distributed in the general population, and expertise, which is either normally (in very selective samples) or exponentially distributed. Combining the normal distribution of intelligence and the skewed distribution of expertise results in a skewed distribution, which may explain why the distribution of creative achievements is also skewed (Den Hartigh et al. 2016; Simonton 1999a).

Phenomenon 4.

Creative achievements across a career follow an inverted U-curve.

Archival studies show how creative achievements unfold over the career of a creator, be it a scientist, composer, or painter (e.g., Ericsson 1999; Kozbelt 2008; Simonton 1997). What these studies tend to show is that the relationship between the number of creative achievements and career age follows an inverted U-shape, where the number of creative achievements of a creator steeply rises in the early decades of a career, then plateaus and slowly declines. The increase in creativity early in a career can be perfectly explained by expertise development, where the age curve for productivity appears to be a function of career age rather than chronological age (e.g., Khan and Minbashian 2019). Immersion in a domain over time leads to an increase in knowledge, activities, constraints, skills and procedures of a particular domain (Kozbelt 2008). By enriching the knowledge base in a particular domain, the creator has the necessary building blocks for creative work in that domain (Ericsson et al. 1993; Simonton 2008; [4] 2018). However, assuming that creators continue to develop their expertise across their career, why do their creative achievements not show a similar linear increase? Apart from extraneous factors that are beyond the scope of MTCA (e.g., successful scientists get managerial positions that limit their time to express their creative ability), the plateauing of creativity can be explained by how the acquisition of expertise follows an S-shaped curve: after a period of steep increase the acquisition of expertise levels off (Krampe and Charness 2018). That creativity ultimately declines may be caused by various extraneous factors such as poor health or changes in priorities or interest (Kozbelt 2008), but can also be explained by the fact that cognitive abilities, in particular what is generally considered as fluid intelligence, tend to decline during adulthood (Salthouse 2009). Simonton (1997) presented an endogenous explanation of these growth patterns. In future work an elaboration of the MTCA formula in such a dynamic model might be of interest.

Phenomenon 5.

Limited effects of creativity training.

Many forms of creativity training exist, most of which focus on the enhancement of a specific ability, such as divergent thinking or convergent thinking (Scott et al. 2004). Many studies show that creativity training effects are generally limited to the abilities that are specifically targeted and hardly generalize to real-world creativity (Baer 2012; J. M. Baer 1988; Scott et al. 2004). This lack of transfer makes perfect sense according to the MTCA. People rely, not on single, but on many cognitive abilities to turn domain specific expertise into real-world creative output. The same studies also show that creativity training effects tend to increase when creativity training is applied to exercises and examples within a relevant domain (Scott et al. 2004). This small, but nevertheless robust strengthening effect, also makes perfect sense according to the MTCA. Real-world creative output builds on domain specific expertise and relevant examples and exercises during training may help people to successfully apply newly acquired skills in their field of expertise.

Phenomenon 6.

Absence of a specific neural basis of creativity.

Decades of research exploring the neural correlates of creativity fail to show a specific brain area involved in creativity (Dietrich and Kanso 2010). If anything, this works shows diffuse prefrontal activation during the performance on creativity tasks (Dietrich and Kanso 2010). In line with this finding, more recent neural models of creativity include a large prefrontal network that is implicated in controlled memory retrieval and central executive processes ([6] 2018). This is much in line with the MTCA, which predicts that performance on creative ability tests relies on many cognitive abilities that underlie intelligence in general.

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