Proposing the Cognitive Space Theory: A Map to Explore the Mind

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Thesis Summary

This thesis attempts to answer a central question in the field of creativity: *what creativity looks like in various domains of activities*? Finding a satisfying answer to this question involves answering many more questions. Therefore, the first chapter is dedicated to establishing a shared understanding of the term 'creativity'. Following this, determining what creativity looks like in various domains is answered in that same chapter with a new theory of cognition, called the *Cognitive Space Theory*. This theory organizes the content of domains according to ten fundamental cognitive spaces. These cognitive spaces cover a broad range of human creative expressions. In the second chapter, a questionnaire based on the theory is developed and validated. This questionnaire assesses the exploration and mastery of the ten cognitive spaces postulated in the theory. The results of two studies are reported to demonstrate the psychometric properties of the questionnaire. The third chapter uses the latter questionnaire to predict the creative activities and creative accomplishments of university students in eight different domains ranging from sport to science. Finally, the fourth chapter discusses the implications of the theory for education. The chapter concludes with future avenues of research in neuroscience, cognition, and artificial intelligence.

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Abstract

This chapter answers a very central question within the field of creativity, namely: *how creative thinking unfolds in various domains of activities*. To tackle this issue, we start by establishing a shared understanding of the concept 'creativity'. Creativity is approached from a socio-cultural perspective, whereby the process of generating novel and valuable ideas and products is distributed among a manifold of individuals, tools, and systems. We follow that definition with an answer to the question *creative for whom?* We propose that those who *consume*, figuratively or literally, a product or an idea can be considered the judges by default of that product or idea. The chapter proceeds with a description of the components required to become a *creator*, i.e., someone who makes new and valuable contributions to a society. Considering that creators must specialize in a domain of creation, the question of what creativity looks like in various domains becomes crucial and has yet to find a satisfying answer. To resolve this issue, we propose a new theory of cognition, called the *Cognitive Space Theory*. This theory organizes the content of various domains according to ten fundamental *cognitive spaces*. An overview of each cognitive space is provided with examples of their relationships with known domains of activity. Lastly, we discuss the assumption of the theory and its relationship with the construct of *openness to experience* as well as with respect to *divergent thinking* abilities. The contribution of this chapter lies in its proposition of a new theory of cognition. The Cognitive Space Theory integrates influential models of creativity in an elegant framework, without contradicting previous findings and theories.

Key words: Cognitive Space Theory; Creativity; Domain-specificity

Chapter 1

Title: Proposing the Cognitive Space Theory as A Map to Explore the Mind

Creative thinking is often cited among the top skill to master in order to work and live successfully in modern societies (Conner et al., 2018; Trilling & Fadel, 2009; Zhou, 2017). Educators, entrepreneurs, community leaders, and policymakers have identified creativity alongside lifelong learning, problem solving, cultural understanding, communicating complex ideas, and using technology, as the skills to be developed by the next generation of workers (Partnership for 21st Century Skills, 2008; Robinson, 2011; Rosen et al., 2020). All over the world, governments are investing vast amount of resources into education programs designed to foster the creative thinking of students in anticipation of upcoming challenges (Barbot et al., 2019). Research within the field has mainly focused on the idea generation phase of the creative process. For example, personality traits such as openness to experience, cognitive mechanisms such as divergent thinking, and the quality of one's motivation have been reliably associated with the generation of creative ideas (Amabile, 1983; Feist, 1998; McCrae, 1987; Wallach & Kogan, 1965). Among the questions which remain largely unanswered by researchers is how creativity manifests itself in various domains of activities. For instance, what does creativity looks like in politics, cooking, and engineering? Answering this question is important to nurture creativity in these disciplines.

The current thesis introduces a new way to think about the content of disciplines. The *Cognitive Space Theory* is elaborated in this chapter to determine how creative thinking unfolds in specific domains and what is the kind of overlaps that can be expected between different them (Baer, 2016b, 2016c). To answer those questions, we must first establish a shared understanding of the term 'creativity'.

The Nature of Creativity

A major question in the field of creativity is whether creativity is a general ability or a domain-specific one (Baer, 2012; Barbot et al., 2016; Plucker & Beghetto, 2004). Said otherwise, if you are creative, are you creative in almost everything, or are you creative only in a limited number of domains? Answering this question has consequences on how we define creativity, how we speak about it, how we measure it, and how we design interventions to enhance it (Baer, 2012, 2016a, 2016b; Sternberg et al., 2004). For example, if creativity is domain general, training in any discipline may enhance it, but if creativity is domain-specific, training in one discipline may enhances a creative potential in that discipline only. Thus, training in multiple disciplines would be required to fully develop one's potential.

Researchers remain divided on this question. At first, the field leaned heavily toward the domain-general view, influenced by the G-factor of intelligence (Baer, 2016c; Nakamura & Fajans, 2014; Weisberg, 1993). More recently, the domain-specific view of creativity has garnered more support (Baer, 2016b; Plucker, 1998; Plucker & Beghetto, 2004). Overall, researchers now agree on a balanced view whereby creativity result partly from general abilities, partly from a set of domain-specific abilities and domain-knowledge, and partly from a set of task-specific abilities (Barbot et al., 2016; Kaufman & Baer, 2004a; Lubart & Guignard, 2004).

The lack of consensus surrounding this question might come from the question itself. Even though the question possesses many variations, it often boils down to whether creativity is a domain-general or domain-specific *ability* (e.g., Barbot et al., 2016). This is problematic as soon as we consider creativity not as an ability, but as a *process* (see Plucker & Beghetto, 2004).

Creativity Is a Distributed Process, Not an Ability

To define creativity, a useful distinction has been made by earlier theorists between the *process* and the *product* (Rhodes, 1961). Formally, "creativity" is commonly defined as the *generation of products which are novel (i.e., original) and valuable (i.e., useful, task appropriate, effective, or meaningful) as judged by oneself or others* (Csikszentmihalyi, 1999; Forgeard & Kaufman, 2016; Runco & Jaeger, 2012; Stein, 1953; Sternberg & Lubart, 1999). We use the term "product" broadly here to refer to any proposals (such as an idea, a sketch, or an actual product). Although creativity is often interpreted as referring to an ability, *generating something* is more accurately framed as a process. This distinction is important because an ability is located at the individual level, whereas a process can be distributed across many people, tools, and systems. A very common mistake while discussing the concept of creativity is to assume that it is situated in the individual's mind; as if creativity comes from one person and involved nothing else. However, ideas and products come from the interplay of a multifold of people and resources (Clapp, 2016a, 2016b; Corazza & Lubart, 2020; Glăveanu, 2010, 2014, 2015; Hutchins, 1995). For instance, producing an original photography results from the invention of cameras, access to a location — which may involve cars, planes, streets, shoes — the luxury to invest time in that activity, a subject, the use of photo editing software, and so on. In addition, an understanding of colors, lighting, visual angles, and conceptual elements can prove beneficial to render the beauty of the scene. Thanks to earlier creators: theories, tools, and technics have been developed, such that the production of any photography combines the creative work and effort of many thousands of individuals (Clapp, 2016b; Clapp & Hanchett Hanson, 2019; Glăveanu, 2011). And thanks to modern creators, high quality cameras and other tools are accessible, and

the result can be printed or shared on online platforms to a wide audience around the globe. In brief, there is no idea, nor products, which do not depend on the collaboration of many creators.

Notice that most creative goals (e.g., taking a photography, cooking a meal, scoring a goal in a football match, communicating to people, generating an equation) involve many steps which are not in and on themselves considered "creative" (e.g., practicing a movement over and over until one has mastered it, practicing reading, practicing mathematics, …). These repetitive and predictable steps are nonetheless essential to the creative process. Certainly, to write a book, one must learn how to write. These "non-creative" skills are part of the process of creation. In fact, everything which influences a final product is part of its creation process. This includes other people's ideas, the resources made available, opportunities and discussions, sleep schedules, alimentation habits, emotions, failures, successes, goals, learning experiences, support systems, and more. All these aspects constitute the process of creation (not only contributes, but constitutes it; Csikszentmihalyi, 1999).

Being a creator, i.e., someone who proposes new and valuable ideas or products, is one role among many others. Acknowledging that creating a product, or simply generating an idea, is a distributed process — rather than a single individual operation — does not diminish the importance of the role of the creator. The creator is the one who takes the risk, centralizes the resources, summarizes the information, influences the direction of the final product, and concretizes a unique vision (Clapp, 2016a). The point is that creators are not achieving their vision by themselves, nor do they develop their visions by themselves. Creators are embedded in a larger system. In brief, any creative product results from all those steps which started many years ago, when the possibilities were not even the same, and from the work of many creators with overlapping goals.

Creative For Whom? Judging the Creativeness of Products

According to the common definition, the creative process is one which generates ideas or products that are *valuable* and *novel*. The criterion of value and novelty have reached a high consensus among creativity researchers (Barron, 1955; Batey, 2012; Boden, 2004; Mednick, 1962; Plucker et al., 2004; Puryear & Lamb, 2020; Runco & Jaeger, 2012; Simonton, 2018; Stein, 1953; Wallach & Kogan, 1965; but see Corazza, 2016 and Weisberg, 2015). These criteria filter out proposals which are only novel. For example, proposing to solve a plumbing problem by turning the light on and off twenty times in a row is perhaps novel and original, but not valuable, therefore not considered creative. The associative mechanisms behind the generation of novel ideas are interesting in and on themselves (e.g., Beaty et al., 2021), but these ideas would not be considered creative. The two criteria also rule out proposals that are only valuable without being novel. For example, solving a problem with a known solution is valuable, but the lack of novelty prevents it from being considered creative. The criterion of value and novelty are multiplicative (e.g., Simonton, 2018), such that a zero on one axis cancels the total score. This opens up for various degrees of creative quality. In essence, the more valuable *and* novel an idea is, the more creative it is.

In her insightful paper, Amabile (1983) noted that despite their elegance, these two criteria were very difficult to assess objectively (see also Weisberg, 2015). Indeed, what is considered valuable — or even novel — is dependent upon the culture, social norms, the context, and subjective preferences (e.g., aesthetic preferences). In sum, it is dependent on a frame of reference. Therefore, Amabile acknowledged that a creative product was a subjective construct and decided to work with it as is, instead of trying to objectify it. Accordingly, the best way to judge whether something is novel and valuable would be to ask appropriate experts (Amabile,

1983; Kaufman & Baer, 2012). Experts can reliably evaluate the novelty of an idea based on their knowledge of what has already been proposed in the field and their own search process. They can also evaluate its value based on those same reasons and by the fact that they are the ones most likely to use it and appreciate it. For example, to determine whether a line of jazz is creative, ask jazz experts; not hip-hop experts. To judge whether a scientific manuscript is a creative contribution, ask science experts in the relevant field.

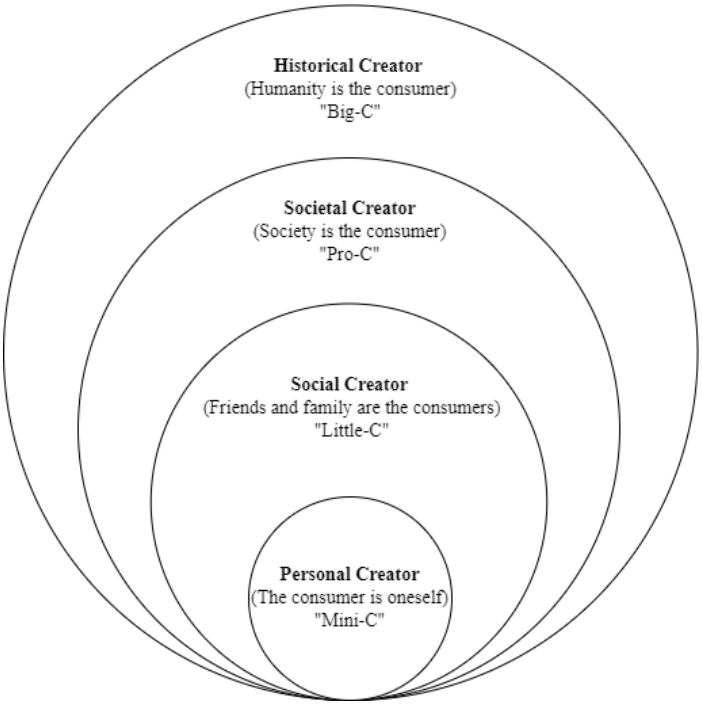
One caveat of using experts as the gold standard to assess the creative quality of productions is that it runs the risk of overlooking more modest proposals. For instance, a child drawing is commonly considered a creative product, but for relevant experts, its lack of novelty or value to a field takes away its creative quality. For this reason, Beghetto and Kaufman (2007) have proposed to call *mini-creativity*, or in short “mini-c”, the type of creative products which involve personally meaningful and new connections. Mini-c can evolve into “little-c” when the idea or product is being recognized as creative by other people. It evolves into "pro-c" once professionals and experts considers it creative (Kaufman & Beghetto, 2009). The final stage is "big-C", where the proposition is considered highly creative by many people and for many years. The categories of creators are showed in Figure 1.

I would like to propose a complementary way to address the question: creative for whom. One way to answer that question is to consider the *consumers* of a product or an idea as the ultimate judges. Whether we think of it figuratively or literally, people consume the creative quality of products and ideas. For example, watching a movie or listening to a music are ways to consume these types of products. People tend to re-watch the same movies and listen to the same song in loop. The consumption of a product or idea suggests that there are some value or novelty to it. This framework suggests at least four levels of creators. The first level is *personal creator*,

it corresponds to being the only consumer of one's own product. For example, whenever a musical composition is only listened by its composer, that creator has attained the category of *personal creator* — whereby the only relevant judge is oneself. Sharing the composition to other people enables new audiences to consume it, appreciate it, and criticize it. It does not necessarily change the product, but it changes the social status of the creator. For example, if friends and family listen and appreciate one's musical composition, one has reached the second level, namely the *social creator*. This second level involves individuals who personally know the creator, such as friends, colleagues, and family members as consumers. Knowing the creator typically lowers the standards due to the fact that people can appreciate the effort and are more likely to account for the process. The example of a child drawing may fall in that category considering that the product is relevant mostly to family members and friends. The third level involves strangers, professionals, and experts as the consumers. This level is called the *societal creator*. Examples of that level include published scientific articles, published books, and exposed work of arts. Another example would be a dance video shared on social media which becomes viral. When strangers genuinely appreciate a product, this indicates that the product has value to offer in comparison to other products being generated in the field. The fourth and last level involves humanity itself as the consumer. This level is called *historic creator*. Creators (or collaboratives) which reach that level witness their work being consumed by a large proportion of humanity and for a large period of history. Mathematics, languages, architectures, music, movies, cooking recipes, inventions such as the elevators, cellphones, guns, and the laving-machine, are some examples of historic contributions. Importantly, different aspects of a product can be consumed. For example, a child drawing can be visually consumed or emotionally consumed. The component being consumed points to where the value or novelty lies. For

example, most often than not, parents consume a child' drawing as an emotional product, whereas the child may see genuine value and novelty in its visual aspects. Hence, the drawing would place the child as a personal creator in the "image" space but a social creator in the "emotional" space. For the example of a viral dance video, thousands of individuals sometimes watch the same video. However, dance videos are not always consumed for the quality of the choreography itself, but sometimes for a humoristic component or because the dancer is considered physically attractive. In these latter cases, what is being consumed is not so much the movements, but rather the story, the emotion, or a mix of them.

Figure 1. Four levels of creators based on the status of the consumers.



Note: The mini-c, little-c, pro-c, and big-c model comes from Beghetto and Kaufman (2007) and Kaufman and Beghetto (2009).

The idea of consuming a product, and making the appropriate judges those who consume it, has the advantage of allowing to track which aspect of a product is considered creative and by which audience. Distinguishing between levels of creators matters because being a creator at the personal level is quite different and much more accessible than being a creator at the societal

level. Societal creations require sharing the product, promoting it, and seeking approval of a community, which may require a high level of mastery and complying to external standards (Gardner, 2011; Weisberg, 1993). Historical contributions are based on more unpredictable factors. Notice that reaching a higher level does not override previous levels. The novelty and value that creators subjectively ascribe to their works is the only thing that matters for personal creators. Interestingly, pursuing the path of personal creator necessarily leads to self-improvement, because the next project must be new and valuable compared to one's own past proposals. This framework allows some individuals highly creative at a personal level to be rejected by peers, or vice-versa (i.e., creators rejecting themselves while being adored socially). For example, Vincent Van Gohg has registered only one painting sold during his lifetime. His devotion and passion for painting was evident throughout his life. Van Gogh prioritized his art and continued to pursue novelty and value according to his own standards despite a lack of social recognition of his talent. His paintings became famous after his death and he is now considered one of the greatest artist of all time. The paradox of being highly creative but socially rejected for a period of time is not a contradiction under this framework. Arguably, Van Gogh is a personal creator, and he remains so despite becoming a historical creator after his death. In brief, this framework parsimoniously embodies the subjective nature of labelling a product as creative or not. It straightforwardly determines which level a creator (or a collective) has reached with a particular production. Moreover, once we identify *what* is being consumed in each production, we can break down which aspects of a production is being considered creative and at which social level.

The Journey to Become a Creator is Paved with Domain-Specificity

How can someone come up with ideas or products that are novel and valuable to oneself or others? As mentioned earlier, the creator is one role among many others. To become a creator, it is necessary to invest time in a domain of predilection. Indeed, the journey to become a creator is paved with domain-specificity.

In her componential model, Amabile (1983) identified three necessary components to produce work deemed creative by professionals in a field. Thus, her model applies to societal creators. This being said, the components are also relevant to personal and social creators (see Figure 1). The three components are: *task motivation*, *domain-relevant knowledge and skills*, and *creativity-relevant skills*. To a large extent, each of these components are bounded by domain-specificity.

Motivation. Feeling passionate about something is essential to propose creative ideas relevant to experts in a field. This is true in large part because others have already tackled the matter beforehand. They have thought of many possibilities and tried many combinations already. Therefore, to propose something new and relevant in a field, one must either be lucky or also among the passionate who challenge and scrutinize the possibilities (Amabile, 1993; Hennessey, 2019; Vansteenkiste et al., 2004).

Motivation is the mechanism responsible for self-regulation. It regulates our behaviors, it is what gets them started, directs them, energizes them, and sustain them (Graham & Weiner, 2012). Because of that, motivation is involved in the acquisition of knowledge, skills, and their execution. Motivation is one reason the process of creation has domain-specific components (Plucker & Beghetto, 2004). Indeed, some people enjoy playing basketball, while others do not.

Having no interest in an activity makes it very unlikely that one will search for novel possibilities within that field.

Domain knowledge. Contrary to some misconceptions, acquiring knowledge and techniques relevant to a field contributes to one's creative potential (Baer, 2015; Weisberg, 1999, 2006). Indeed, creative ideas build on top of previous ones. In order to propose something new and relevant to others, it is important to be mindful of what others have done, what is working, and what is currently needed. To move a field forward, one must understand what the possibilities are, what the problems are, which solutions have been proposed, and why those solutions are working or not (Gube & Lajoie, 2020; Weisberg, 2006).

Acquiring domain knowledge opens up the possibilities in a field. More combinations become available by the acquisition of more units of knowledge, tools, and technics. Many domains of creation have developed specific technics. For instance, music relies on a plethora of audio effects (e.g., reverberations, delays, saturation, compression, …) to produce, refine, enhance, and explore sounds. Failing to use those technics will likely result in lower quality productions. These tools and technics contribute to raising the quality, depth, and number of possibilities in a field. Mastering those technics, as the analogy goes, implies that you have more string to your bow. Creativity is not so much about reinventing the wheel, it is a collaborative process. To realize ambitious creative projects, it is wise to collaborate with others and rely on things which work. As another example, consider the scientific enterprise. New statistical models and technological advances, such as FMRI, EEG, brain network analyses, and structural equation models, have allowed new analytical and methodological possibilities. New knowledge is reachable, thanks to those advances. Knowledge combines into new, better, refined, and more

valuable propositions. In brief, to become a societal creator, it is important to acquire and master the basic knowledge of a field.

Creative Skills. The last component of Amabile's model is creative skills. Creative skills can be understood as heuristics, technics, tools, and practices that help explore uncharted territories (Boden, 2004; J. P. Guilford, 1967; McFadzean, 2000). Creative skills are often conflated with the very concept of creativity. However, creative skills alone do not cover the entire creative process. As described above, domain-knowledge, resources, tools, and other people, are crucial and interact with creative skills in the generation of ideas.

Creative skills include divergent thinking (i.e., generating variations), associative thinking (i.e., generating semantically associated ideas), critical thinking, incubation practices, improvisation, analyzing paradoxical instances, considering the opposite point of view, seeking analogies, being open to experience, and more (Jaccard & Jacoby, 2019; McFadzean, 2000). Essentially, creative skills are *exploration skills*. While exploring possibilities may not always lead to valuable ideas, it certainly increases the odds of finding some. Boden proposed three categories of creative skills, which she called *combinational*, *exploratory*, and *transformational* (Boden, 2004, 2007). Briefly, combinational skills involve the combination of *familiar units* into novel and valuable sets. Accordingly, familiar units (such as words, musical notes, or colors) can be combined into an almost infinite number of ways (assuming a large space), and any combination which is simultaneously novel and valuable is regarded as creative (Boden, 2004). By contrast, exploratory skills involve the exploration of new units and new possibilities. This includes seeking new knowledge or new ways of doing things. For example, a researcher might learn about new topics, delve into new analyses, or look for new tools to research a phenomenon. Discovering new units expands the combinative opportunities. Lastly, transformational skills

involve the alteration of rules and transformation of constraints. Transformational skills fundamentally alter structures such that previously impossible combinations are now judged legitimate and valued (and previously possible combinations might no longer be valued). For instance, Albert Einstein's theory of general relativity opened up the possibility that gravitational waves could propagate in the space-time manifold; a prediction inconceivable before his theory, and confirmed much later, in 2016 (Abbott et al., 2016). Transformation skills does not mean removing the structure, it means proposing a new structure which adds value (Boden, 2004; Veale & Cardoso, 2019). As an example, the ace in a deck of cards was initially a 1 and the weakest of the cards; however, it is now the strongest card.

Defining the Spaces of Possibilities

Understanding the specificities of each domain is important to understand the creative potential of individuals (Beghetto & Kaufman, 2009). The model of the creator presented above implies that a significant amount of time and effort is devoted to the mastery (i.e., acquisition of domain knowledge and skills) and the exploration (i.e., the use of creative skills) of a domain of creation. Consequently, professional creators typically lack the time and energy to master and explore many domains; and thus become significant contributors in a limited number of them (Baer, 2012; Kaufman & Baer, 2004; Plucker & Beghetto, 2004; Szen-Ziemiańvka et al., 2017). Nonetheless, if knowledge and skills could transfer from one domain to another, then creators would at least develop a potential in those connected domains.

There is currently no theory which satisfactorily answers the question of what knowledge and skills can transfer from one domain to another (Baer, 2012; Goldstein et al., 2017). Likewise, there is a clear lack of understanding of what is taught and learned in domains of activities and

therefore no grounded theoretical reason to expect transfer (Goldstein et al., 2017). A first step is to delimit the boundaries of the term “domain”.

Defining the word “domain” in a consistent way is challenging. Generally speaking, we can define a domain as an organized sphere of activities. Examples of domains include soccer, natation, chemistry, physics, photography, politics, law, first person shooter video games. The extent to which the term domain should refer to specific (e.g., first person shooter video games) or less specific activities (e.g., video games) is not so clear and is in fact the bulk of the issue. The Amusement Park Theory is one attempt to organizes the degree of specialization of domains and activities in a hierarchy (Kaufman & Baer, 2004a). Within this framework, the term “domain” is positioned below general themes (such as art and science) and above specialized activities (such as Haiku, first-person shooter video games, or a specialized methodology in physics). Domains belonging to the same general theme should have more in common than domains belonging to different themes. Hence, although tennis and badminton are two different domains, they both fall under the general theme of sports and therefore are expected to share some overlap. One important issue with the concept of domain stems from the fact that they are not homogeneous. Each of them is made up of many types of content. For example, cinema is a complex domain which involves visual, auditive, emotional, and strategic components, to name a few. Hereafter, I propose the Cognitive Space Theory (CST) as an attempt to explain the composition of various domains. The CST assumes fundamental and stable *cognitive spaces*, which capture the possibilities of our mind, and thus constitutes the basis of our experiences and activities.

The Cognitive Space Theory

The Cognitive Space Theory is a classification system — a map so to speak. It classifies our mental content according to ten fundamental cognitive spaces. Those cognitive spaces are defined at a computational level. More specifically, each space possesses identifiable units. Those units are what creators combine, explore, and master. The ten spaces identified by the theory are: *movement*, *sound*, *image*, *sensation* (i.e., odor, taste, touch), *emotion, strategy*, *story*, *symbol*, *network*, and *system*. The spaces are shown in Figure 2 and are defined in Table A1 of the appendix.

The cognitive spaces of the theory were identified by following a set of rules and assumptions. First, each cognitive space had to possess combinable units. If a space' units were unidentified, the space itself was unidentified. The name of the spaces betrays their combinable units. For example, *movements* are being combined in the Movement space, *symbols* are being combined in the Symbol space, and *systems* are being combined in the System space, and so on. Second, the spaces should be relevant to more than one domain. This rule is not a strict one, but if a space underlies only one domain that we know of, it is very unlikely that this space is fundamental or, at the very least, it lacks practical explanatory power. Thirdly, we should be able to imagine each space as existing by itself. Said otherwise, although the spaces interact with one another, each space should remain meaningful even if all the other spaces were to be artificially removed. This rule contributes to obtaining a parsimonious number of spaces. Fourth, the spaces describe nominally different types of information. The Cognitive Space Theory is a theory of information and despite that some spaces might possess more possibilities than others — or covers more grounds than others—, they are nominally categorized, and therefore qualitatively and hierarchically equal. Hence, no space should feel above or beyond the others. Lastly, the

spaces, together, should cover all the current and past domains and problems that the human mind has ever encountered. Cognitive spaces are stable and cover all the possibilities of our mind. Old and future domains and problems are likely to fall within existing cognitive spaces. However, it is not impossible for the mind to evolve towards new cognitive spaces, if a new type of information is discovered and can be successfully exploited.

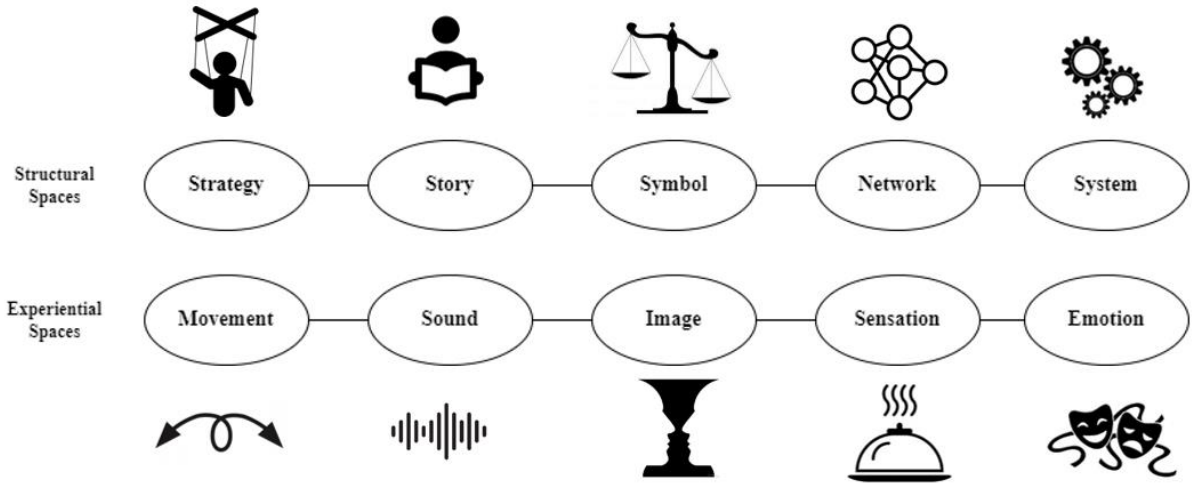
These rules and this computational approach led to the identification of ten cognitive spaces, which presumably covers all domains of activities. After identifying those ten spaces, an elegant organization was noticed, whereby five of the cognitive spaces identified by the theory corresponded to *experiential* spaces, i.e., closer to the human's senses. They are *movement*, *sound*, *image*, *sensation* (i.e., odor, taste, touch), and *emotion*. The remaining five spaces corresponded to *structural* spaces, they are *strategy*, *story*, *symbol*, *network*, and *system*.

The ten spaces of the theory answer the following three questions across a wide range of domains: What do people enjoy about this domain? What are the products generated by creators in that domain? What are the units that creators combine within that domain? For example, consider the domain of politics. Politicians may enjoy politics because of the impact they have on society. Through the institutions they put in place, the laws they adopt, the systems they steer, or the momentum they garner around an idea, politicians can move the society in a direction. Some politicians may enjoy the game of social influence as well. Obviously, not all politicians enjoy politics for the same reasons. The creative products that politicians generate are the systems, such as health care, education, or social redistribution systems; the strategies such as managing resources and fixing objectives; the networks which include people, ideas and businesses; or the emotions they inspire. These creative products correspond to the cognitive spaces. Lastly, what are the units being combined by politicians? Said otherwise, to use the

metaphor of music, what are the musical notes politicians play with? Politicians combine familiar systems, familiar strategies, familiar networks, and familiar stories, in new and valuable ways.

Notice that most domains navigate more than one cognitive space at the time, while distinct domains sometimes navigate the same spaces. For example, scientists are interested in understanding phenomena. This latter objective is achieved to a large extent by thinking the world as a coherent *system*, with interacting parts. However, the scientific methodology calls for the *strategy* space as it involves planning and optimizing one's design based on the available resources. Additionally, the *symbol* space is exploited when real-world phenomena are translated into numbers or letters. Lastly, the *story* space is exploited by the formulation of theories and their dissemination. This example shows that each domain call upon a unique combination of cognitive spaces and constraints, which ensure the former idiosyncrasies. When distinct domains exploit the same cognitive spaces, this overlap points towards potential transfer of knowledge, skill, and motivation. Thus, the theory makes a unique contribution in the field of transfer. In the following section, we describe the ten spaces of the CST and provide examples of their relationships towards various domains of activities.

Figure 2. An organization of the Ten Spaces of the Cognitive Space Theory



Note. The five upper spaces are *structural* spaces. The five lower spaces are *experiential* spaces.

The Movement Space

What are the communalities between the domains of natation, soccer, basketball, dance, horse-riding, car driving, boxing, and e-sports? According to the CST, they all exploit the space of *movement*. Simple movements, such as moving forward, moving backward, or jumping, can be combined into complex sets. Events like the Olympics are watched by thousands of individuals across the world. Those spectators "consume" the best *movements* in the world by watching elite athletes competing. Creative athletes are those who propose original and valuable combinations of movements.

Consider e-sports and how creativity manifests in that domain. Should video games be considered a sport? This is not really the question of interest here. Our interest is in the cognitive processes underlying a domain. Video games involve difficult movements. The difficulty comes from the precision required, the complexity of the combinations, and the speed of execution (Hallmann & Giel, 2018; Steinkuehler, 2020; Witkowski, 2012). Those very same elements help distinguish talented soccer players, talented golfers, talented dancers, and talented drivers from

less talented ones. In fact, these elements, i.e., aim, speed, timing, rhythm, coordination, endurance, directionality, orientation, and more, are elements to be mastered and explored by creators in search of novel movements. The space of movement is not only explored by e-sports and traditional sports players, but also by instrument players (think of virtuoso), cooking chef, surgeons, and many technics used in construction, painting, and sculpting. The space of movement is differently explored by different domains. For instance, the ceiling of endurance is explored by marathoners. However, aim, directionality, speed of execution, and coordination, are more important in football, competitive e-sports, and instrument playing, than in marathon. Together, traditional sports, instrument playing, horse-riding, car driving, and e-sports are all contributing to exploring the possibilities of the movement space.

The Strategy Space

People rarely think of strategies when asked about their creativity. I believe this is due to a failure to contemplate strategies as products. Consider the following, from a very young age, children are questioned about what job they would like to do in the future. Having a goal is a first step into the world of strategy. Afterwards, the many choices individuals make to bring themselves closer to that goal are strategic moves. The final product of strategy is the achievement of that goal.

Creators within that space combine tactics, plans, goals, methodologies, resources, information, and the optimization of procedures. Being creative in that space sometimes means having different goals than other people, or different ways to achieve them. Creators of strategies include politicians, methodologists, policy analysts, military tacticians, coaches, sport players, board game players, managers, entrepreneurs, and more. In fact, one can find creative strategists in any competitive settings.

Jobs in politics, administration, and management rely heavily on creative strategists (Bilton & Cummings, 2010, 2014; McLean, 2009). Management is the art and science of handling the resources of an organization. Creativity in that domain often takes the form of optimization. Optimization is the act of making something as fully perfect, functional, effective, or efficient, as possible. It is about finding the strategy which maximizes one or many parameters. In another vein, planning is also part of the strategy space. Planning a sequence of events is what allows us to move with confidence from one state of affair to another (Sloan, 2006). We use planning all the time: for how we dress, how we commute, what we eat, when we sleep, etc. Whenever an outcome is desired, our mind navigates the cognitive space of strategy to find the steps to achieve it.

Another environment where strategy is dominant is within the educational system. More specifically, the pursuit of high grades. Students are heavily rewarded for strategies that maximize their grades. This translates into many students with similar goals, and any tactics which optimize this parameter is highly valuable (Carmack & Galanes, 2013). Creative strategists are often inspired by their experience in various context and combine tactics from various spheres of life (Sloan, 2006). Winning strategies in chess, volleyball, or video games can teach something about the relevant information to consider, the amount of effort to invest, the timing, the type of goals to set, the role of cooperation, the obstacles, the role of chance, the role of misinformation, and so on. These elements apply to other “real-life” decision making situations. Strategic thinking can be difficult, risky, complex, intuitive —but it is learnable. The biggest misconception about this space is to think that strategy involves only planning and procedures (Sloan, 2006). But the world is not always so predictable and many missing pieces and opposing relations and paradoxes must be dealt with. The inherent unpredictability of human

affairs, the role of chance, missteps, and competing goals, provides strategy its depth and challenges (Freedman, 2013). Being able to handle imperfect information is a requirement for strategic thinking—as opposed to eliminating paradoxes and ambivalence (Sloan, 2006).

In brief, strategy is a fundamental space which structures our actions, successes, and failures. Animals have elaborated strategies for matting, finding food, covering eggs, protecting their nest, etc. It has allowed our species to thrive. Strategy starts very young and remains highly valuable throughout our lives, yet it is often overlooked when creativity is discussed.

The Image Space

Before the advent of photography, the image space was explored mainly through painting, drawing, and sculpting. When the first, black and white, photography was taken, the French painter Paul Delaroche (1797-1856), declared: “From today, painting is dead.” As Bellinetti puts it, “Painting did not die that day, but photography was born, disrupting the world and its social order through the creation of new ways to see, understand, and explore” (Bellinetti, 2019, p. 1).

The Image space is explored by clothing, design, architecture, dance, dishes presentations, marketing, painting, drawing, sculpting, crafts, and cinema, among others. This space is about combining colours, light, shadow, lines, geometric shapes, focus, visual angles, front, background, symmetry, and space to create unique images (Hetland et al., 2015).

Technological tools have contributed to the exploration of the possibilities within that space, just like it did with many other spaces. However, technology has not changed our desire to explore images, it simply changed how we did it. Earlier artists used clay, cements, and paints as mediums. Today’s artists use software, digital tools, artificial intelligence, and imaging techniques to create. The historical development of visual arts is a good example that shows how

a domain can change over time, and how each domain is mostly a grouping of technics and rules which enable us to engage with an underlying space (Pelowski et al., 2017). The fact that photography is a different domain than painting, or that drawing on a computer is different than drawing on a canvas, strengthens the need for a stable theory of cognitive spaces accounting for the continuity in these explorative behaviours.

The Sound Space

Music is a very influential medium that explored and gave structure to the sound space. Nevertheless, one can also think of poetry, social interactions, cinema, acting, and teaching as navigating that space. Poetry shares great interest in melodious content, rhymes, and harmonious sounding effect (Perloff & Dworkin, 2009). Likewise, actors are mastering sounds by paying close attention to the voicing of their speech (McAllister-Viel, 2016; Rothman et al., 2002; Zeine & Faulkner, 2005). Similarly, social interactions also depend on correct voicing (LaPlante & Ambady, 2003).

The sound space corresponds to auditory stimulations. Some of the units being combined by creators include volume, pitch, intonation, intensity, and tone. Basic sounds combine into melodic and harmonic arrangements. Playing with one's tone of voice, intonation, pitch, or volume, is what gave birth to signing and music more generally.

Beside music, the cinema industry has also stimulated the development of realistic sound effects, varied acoustic ambiances, and new technics to capture sounds in various situations. Sounds are used in cinema to convey information about the story, suggest emotion, and contributes to the immersion (Chion & Gorbman, 2009). Some movies have made creative contribution not as much for their storyline, but for their soundtrack. The soundscape explored by the cinema industry, as well as actors, musicians, and poets is fundamentally the same.

The Sensation Space

The *sensation* space encompasses the common senses of taste, smell, and touch. Sensation is explored via cooking, perfume, wine tasting, bodily care products, massage, sexual intercourses, and more. Flavors, odors, and the sensation of the skin constitute the boundaries of this space. Specific flavors, temperatures, textures, intensities, and skin pressures are its units. Washing your body under the shower, swimming in a pool, snuggling into a blanket, or receiving a massage, all fall within that space.

In the same way that music is dominant in the sound space, cooking is dominant in the sensation space. As expected, the creative process of cooking is very similar to that of making perfume. For example, expert chef Daniel Patterson and professional perfumer Mandy Aftel described in their books the similarities between their respective domains:

> We found deep common ground not only in the ingredients we used but also in the ways we created with them: how we selected which ingredients to combine, how we fine-tuned a fragrance or a dish, even how we moved through the process, down to all the little decisions we made along the way. We might each choose, for example, to balance the soft, honeyed sweetness of rose with the bright citrus aspects of fresh ginger. Mandy would start by deciding whether it was going to be a spicy ginger scent with a bit of rounded rose or a buttery floral rose with a smidge of bright spice. Similarly, in the kitchen, Daniel might infuse a custard with the sweet, heavy perfume of dried rose, then lift it with the insistent floral spiciness of fresh ginger. Just as perfume is structured scent, flavor is structured taste (Patterson & Aftel, 2017, p. 2).

Most people are not able to differentiate the many sensations they experience when eating, smelling, or touching. Describing these sensations requires a rich vocabulary which

enables the mind to identify and isolate the subcomponents of sensations (Parr, 2019; Stuckey, 2012). Despite that taste and smell are commonly associated together, the sensory system also includes the chemical sensitivity of the skin (i.e., touch), which plays a role in sensations of warmth, cold, and pain (Green, 1996). For instance, "peppermint evokes coolness and sting because menthol stimulates cold fibers and pain fibers (nociceptors), and chili pepper evokes burning because capsaicin stimulates heat-sensitive pain fibers" (Green, 1996, p. 416). Without smell, the world feels emptier. Individuals suffering from anosmia (loss of smell) or ageusia (loss of taste) report a loss of connection to the world and their surroundings (Pallanti, 2020). As described by Tafalla based on her own experience as a congenital anosmic, odors have an "enveloping effect" (Tafalla, 2013, p. 1293). When people are in a pine forest, they feel surrounded by the aroma of the pines, which reinforces their sensation of being within a pine forest (Tafalla, 2013). Likewise, a person who suffered a traumatic brain injury reported:

> Life lost a lot of its savour—one doesn't realize how much "savour" is smell. You smell people, you smell books, you smell the city, you smell spring—maybe not consciously, but as a rich unconscious background to everything else. My whole world was suddenly radically poorer (Schildkrout et al., 2021).

Cooking is one of those domains where many people are creatively involved in, yet because it is not part of the so called "art category", most people overlook it. The sensation space is deep and complex, thus it offers many creative possibilities.

The Emotion Space

Emotions are a fundamental aspect of human experience. The emotion space is composed of states which can be understood as units, similar to the units composing the other spaces. Within the CST, emotions are understood as creative products. Creators within that space

propose new and valuable emotions for members of a society to consume. For instance, a movie, a book, or a song will propose complex moments of joy, sadness, and worry. The emotion space includes combinable units such as joy, sadness, fear, disgust, loneliness, pride, trust, and hunger. Each of which are intricates and subtle states, decomposable into smaller parts and combinable into more complex states.

The domains of social interactions, religion, spirituality, theater, poetry, therapy, cinema, music, literature, and marketing are exploring the possibilities of emotions. Social interactions in particular offer many opportunities to hone one emotional skills, because social interactions almost always involve an emotional transaction (Fischer, 2009). Even trivial discussions about the weather involve an emotional transaction, which role is to fill 'awkward' silences. Example of creators of emotions include professional actors. Their ability to produce convincing emotions derives from a long work of sensibilization to their own and other people's emotions, an exploration of alternative emotions to the same situation, a mastery of the display of emotions, and an understanding of the subtilities of emotions (Konijn, 2000).

Displaying adaptive social behaviors is a sign of emotional mastery. It involves correctly decoding and correctly responding to an emotional proposal (Goleman, 1996). Mastery of the emotion space has been framed according to the concept of emotional intelligence. The latter involves adaptive emotional responses to situations (Averill, 1999, 2004; Kuška et al., 2020). In contrast, empathy is a creative skill that can be used to explore that space.

An emotionally creative individual goes beyond stereotypical emotions and seek states which are more complex and not anticipated (Ivcevic et al., 2007). This can be achieved through a set up, particular behaviors, discussions, through a medium such as a painting or music, or by embodying a particular emotion. A good example of an emotional-product is a surprise birthday

party. The emotion is part of the gift. The surprise is consumable, and it is more satisfying than a simple party. Giving a gift that one has crafted is also an emotional-product, for which the emotion (and the symbol) is sometimes more valuable than the actual object. In another vein, therapy is another vehicle for the exploration and understanding of emotions. Similarly to how various sports are contributing to raising everyone's understanding of the possibilities of movements, therapy, poetry, acting, social interactions, cinema, music, and other domains, are all contributing to everyone's understanding of the possibilities of emotions.

The Symbol Space

Mathematical symbols, numbers, words, road signs, musical notations, waving to say hi, are examples of symbols that fill our everyday life. By definition, a symbol is something which stands for something else. For instance, words are abstract characters which by themselves have no meaning. The fact that words stand for something else gives them their usefulness. For the mind, using symbols instead of their referent tremendously reduces the cognitive load. For instance, thinking about "love" is made possible thanks to the word-referent which anchors many experiences, feelings, thoughts, and vague impressions, into an easily manipulate unit (DeLoache, 1995; Perlovsky, 2006). The brain needs not activate all those experiences, feelings and thoughts, whenever it wants to discuss love, it can simply refer to the symbol: "love". Even children can refer to this symbol before experiencing it themselves.

Icons, schemas, concepts, and pictograms are the units constituting this space. They combine into higher-order concepts and complex schemas. For instance, the concept of justice can be broken down into smaller symbols: fairness, equality, equity, rights, punishment, and so on (Barsalou & Prinz, 1997). Among the domains which have generated new and valuable symbols, we find religions, politics, mathematics, engineering, language (including all form of

notations), science, philosophy, poetry, marketing, design, and more. For example, technical drawings by engineers, designers, and architects rely on an ensemble of symbols which convey the specific geometry and details about the space and its components. Standardized languages based on symbols limit errors caused by personal interpretation and facilitate the manipulation of real-world referent through their symbolic equivalent (Dixon, 1962; Hiebert, 1988).

The manipulation of symbols is central to many theories of child development (DeLoache, 1995). Children manifest naturally their exploration of that space when they use an object, such as a pencil case, in replacement for something else, such as a phone. This exemplifies one important property of symbols: their schematic nature. According to Barsalou and Prinz (1997), one primary purpose of extracting symbols is to support mental simulation. Simulating entities allow our mind to scrutinize them. Relationships extracted at a symbolic level can be generalize to other cases and events. This allows our mind to understand the symbolic equivalence of metaphor, such as: “love is a fine wine”. Another property of symbols includes their degree of similarities with their referent (i.e., iconicity). As DeLoache puts it, some “symbol-referent relations are purely arbitrary and conventional, with no physical resemblance at all […]. Some are partially iconic: Maps preserve spatial relations, but have few other iconic features. Other symbols are highly iconic: A color photograph, for example, closely resembles its referent.” (DeLoache, 1995, p. 111).

Epistemological questions of whether we perceive reality or only a representation of it are closely tied to the concept of symbols. As the arguments goes, symbols are fundamental for any organism that wishes to interact with the world. The Interface Theory of Perception in psychology posits that human perception is an interface which stands for reality, but is not even remotely close to what reality really is (Hoffman, 2009). It is indeed cognitively advantageous to

work with manipulable and trackable icons and symbols, instead of accurate depictions of reality which would be infinitely more complex and heavier to compute. The difference is comparable to opening up the internet browser and seeing a user-friendly interface instead of HTML and JavaScript codes. The user-friendly interface is not the reality, but this interface provides its user a tremendous cognitive advantage over the seer of lines of codes (Hoffman, 2009). Symbols, as the fabric of our cognition, may imply that the other spaces of the CST are dependent upon this one. However, within the CST, all spaces are assumed hierarchically equal. Plausibly, the Interface Theory of Perception operates at a slightly more fundamental level than the CST. For the mind, this symbolic fabric is taken for granted. The mind redefines symbols as something which stand for something else within the playground of this granted "reality". For instance, we can hear sounds without any additional symbol for it (e.g., no word or image designating it). Hence, symbols are an additional layer on top of this iconic reality.

In brief, symbols are a fundamental part of our functioning. Our minds navigate basic symbolic relationship with ease which allow us to communicate and represent our reality.

The System Space

Examples of systems include computers, cars, clocks, our biology, our psychology, the weather, the economy, physics, etc. A system is by definition an interconnected set of parts organized to achieve a function (Meadows, 2008).

The system space is explored by scientists, politicians, economists, engineers, architects, designers, doctors, construction workers, businesspeople, policy makers, lawyers, and managers to name a few. Systems are made of parts, interconnections, rules, functions, flow, stocks, loops, and more. Seeing the world in terms of systems means thinking not in terms of a static world, but a dynamic one. Instead of looking for who's to blame; system thinkers ask "What's the system?"

because a system can cause its own behavior (Meadows, 2008). Human biology is a system which combines many subsystems, such as the nervous, endocrine, skeletal, muscular, cardiovascular, lymphatic, respiratory systems, and more. The human psyche is also likely a combination of many complex systems, such as the self, memory, attentional, and emotional. However, psychology has yet to reach a consensus on what systems make the list.

Some principles apply generally to all systems. For instance, changing parts in a system usually has the least effect on it. Meadows (2008) gave the original example of a football team. If you change the players on a football team, it is still a football team, although it plays differently— indeed parts of a system are important. Our body replaces its cells every year, but it is still essentially the same body, as long as each new cell carries the same function as the previous one. However, if the interconnections change, the system may be greatly altered. The efficiency of a car's engine, for example, relies heavily on the functioning of the other parts of the vehicle. Therefore, combining the best parts of each car to create a "super-car" will not necessarily result in the best possible vehicle (see Ackoff, 1994). Because the role of each part is dependant upon the other parts of the system. This is why seeing the entire system instead of individual parts is crucial when dealing with systems. Indeed, problems in one area can be caused from elsewhere; and change in one area can cause problems elsewhere.

Not everything is a system. An ensemble without interconnections or without purpose is not a system. For instance, dust scattered on a computer is not, in itself, a system. You can add dust or take some away and you will still have dust on a computer. But add or take away “football players, or pieces of your digestive system, and you quickly no longer have the same system” (Meadows, 2008, p. 11).

The Network Space

A network is like a web, in the sense that one end is connected to the other by way of intermediary connections. Networks are different than systems to the extent that they do not have a particular function. In fact, the only function a network has is to connect things together. Thus, contrary to systems, changing a connection does not change the functioning of the network. Moreover, the connections in a network need not be logical, nor even useful. For instance, I could decide that "piano" is connected to "mouse" in my network, based on the fact that I dreamt of both on a Saturday of this month. In fact, any links can be elaborated based on any reasons. The reasons why things are connected are usually embedded in the types of connections they hold. For instance, a mouse and an elephant could be associated because of there animal status, or because of their clear opposition in size. These are two qualitatively different connections. Categories and meanings are shaped based on the types of connections things hold.

Networks are fundamental to humans: they underlie our relationships, memory, and semantic understanding. Indeed, a growing number of studies are using network science methodologies to study human cognition, in particular memory and creative thinking processes (see Siew et al., 2019 for a review). Networks are combinable and breakable into smaller networks. The combination of smaller networks enable the formation of discrete categories, and members of a category can be members of many categories through logical and hierarchical network structures (Zhong et al., 2007).

The network space is navigated by the domains of literature, philosophy, poetry, social interactions, politics, business, and more. The units of this space are nodes, edges, types of connections, weights, hierarchies, and categories. Philosophy is a discipline interested in defining concepts. It explores networks of associations as a way to ascribe meaning. Likewise,

poetry plays with the meaning of things and look for clever associations which often reveal something about our semantic reality. Entrepreneurs are creating networks made of businesses and people. Similarly, influencers are the nodes which connect a variety of people together. In another vein, the world wide web allowed the connections of millions of people with minimal geographical restrictions and latency. Modern platforms of communication have made major creative contributions in the network space. More recently, the metaverse has promised to add another stone to this edifice. Being creative in the network space means finding new ways to make things and people connect and exchange information or to propose new types of connections.

The structure of networks can be objectively described. Many models of networks have been identified, such as the small-world, scale-free, hub, or star models (Zhong et al., 2007). Each have their own characteristics allowing for quantitative predictions. For example, the scale-free model is a common network where new links are made preferentially to nodes that already have many links. This means that the more connections a node has, the more connections it will have in the future. Within this model, a small number of nodes end up with many links, while a much larger number of nodes end up with only a few links (Zhong et al., 2007). This model can be applied to a lot of complex systems, including businesses, human social networks, and transportation networks.

In brief, networks are present and influent in our everyday life. People, ideas, symbols, and experience, connect in ways which are captured by that space.

The Story Space

All myths—across time and across cultures—contain the same basic ingredients and follow the same general recipe. There are never any new stories—just the same stories retold. And the one

overarching story, the blueprint for tales since humankind's earliest days, is the "hero's journey." - Campbell, 1949, The Hero with a Thousand Faces

Humour, cinema, literature, religion, divination, social interactions, video games, marketing, teaching, coaching, science, history, law, politics, entrepreneurial, and journalism all tell stories.

Small stories combine into complex stories. For instance, most movies tell multiple stories simultaneously: the main character, the villain, a love story, and a side character. Characters are psychological units within this space. Combining characters can be done strategically to explore possibilities. The goals, strengths, and flaws of one character collide with those of another character, and so on. Other combinable units include narratives, plots, events, temporal order, transitions, conclusion, introduction, messages, conflicts, resolution, builds up, and more.

Stories are parts of everybody's life, all the time. They produce experiences that are so absorbing that we seldom notice them. From internet memes, to television, music, and mundane discussions. Our desire for stories is as strong as "the motivations for color vision or sentence structure" (Turner, 1996, p. 5). According to Turner, the small stories that we know best are stories of events in space: "the wind blows clouds through the sky, a child throws a rock, a whale swims through the water" (Turner, 1996, p. 13) These stories constitute our world. They have become so fundamental that when someone says, "Tell me a story," what is meant is something unusual and interesting. But small stories are what we have instead of a chaotic experience (Turner, 1996). We need not to worry about our interaction with the world because we have absolute confidence in these stories. We know these are all just stories because physics offers a

different representation of the world. One “that leaves out agency, motive, intentionality, and a range of structure that is part of ” narratives out of the picture (Turner, 1996, p. 14).

Stories emerged from our needs to make sense of the world. In this regard, they have shaped our networks of beliefs and meaning. Creators of stories have influenced our thoughts, cultures, beliefs, and power relationships. For instance, stories of gods and prophets are historical creative contributions within this space. Some of these stories are still being consumed hundred of years later. These stories have shaped our societies and moral codes. The role of stories for the mind is obvious in small children. Their lives are filled with fictive scenarios. It is something they seem to need. Without any assistance, children play together by agreeing on a scenario, skillfully improvising characters and problems, and acting them out (Gottschall, 2012). The fundamental role of stories is also obvious in dreams. Vivid dreams usually focus on a protagonist —the dreamer —who struggles to reach its objective. These dreams are made of the same units as any good story: a theme, a plot, a character, a point of view, conflicts, attempts, resolutions, etc. (Gottschall, 2012).

In brief, good stories are powerful tools to grab attention and communicate information efficiently. The space of story is deep and complex. Its possibilities are explored and mastered by a variety of creators in domains which can seem a priori quite different. Understanding that the story space underlies many domains can help explore and give attention to the right elements. Hence, a music composer could be inspired by the structure of a good story. This would highlight the need to start with an introduction, then a transition towards a build up to create tension, then a release of that tension, etc. This structure can also be applied to teaching. Being a creative teacher can be achieved by playing a character and telling small stories to communicate bigger ideas.

Discussion

The CST has been elaborated in response to a very central problem in the field of creativity: what creativity looks like in various domains and what is the kinds of overlaps that can be expected between creative performance in different domains (Baer, 2016b). Under the CST, domains are seen as media, or metaphorically act as vehicles, which allow to navigate more fundamental cognitive spaces in socially valued ways. They also enable to woven multiple cognitive spaces into a single product (e.g., a smelly, tasty, and nice-looking meal with a nice sizzling sound). Visual arts were given as an example of how domains may change over time, from painting, sculpting, to photography, cinema, graphic design, and AI-made productions. Despite these changes, there is a continuity in the explorative behaviours of individuals captured by the underlying cognitive space they explore. Each cognitive space is extremely complex and rich in information, yet our minds navigate them with remarkable confidence and ease, which highlights their fundamental nature.

Two assumptions underlie the CST. First, each space is assumed to be hierarchically equal. Consequently, each space is just as important as any other on theoretical grounds. This statement has critical implications for the development of creative potential, for self-actualization goals, for well-being, for education, and for society in general. As a quick example, in many modern societies, the system and symbol spaces are greatly emphasized, with a high valuation of mathematics, language, science, and technology. Although this emphasis is rooted in an economic perspective, it might not be correct under a cognitive developmental one. In contrast, the emotion and sensation spaces are rarely taught in school nor socially appreciated at the same level as the others. The CST can be used to identify the creative strength and weaknesses of

individuals. Those strength and weaknesses can be worked out in order to make progress as a personal creator.

The second assumption of the CST is that each space possesses combinable units. This assumption is based on the combinational skills identified by Boden (2004). Accordingly, each space follows the same logic: it possesses units (such as notes, words, or parts in a system) which can be combined into higher sets or fragmented into smaller units. This rule is particularly useful for two reasons: first, it ensures a systematic approach to creative thinking. More specifically, familiar units can be combined into an almost infinite number of ways. Hence, identifying familiar units is a first step into a systematic approach to creative thinking. Secondly, it preserves the logical consistency of the spaces: all ten spaces operate the same way.

A third statement could go as far as to say that each space should contain correspondences with one another (see also the Theory of Logical Types; Bateson, 2000; Roach & Bednar, 1997). For instance, if basic colors exist, then basic notes in the space of sound, basic emotions in the space of emotions, basic systems in the space of systems, and so on, should apply to all ten spaces. This allow for insight into spaces which are less known based on those who are known better. For example, if notes can combine into harmonies, then emotions must be combinable into higher sets as well.

Bridging Domain-Generality and Domain-Specificity

Numerous specific skills are called upon by each domain of activity (Barbot et al., 2016; Glaveanu et al., 2013). For example, graphic design feels different than sculpting. But this does not mean they do not share a significant overlap. While the movements involved and the resistance of the material might be quite different, the colors, shapes, symmetry, proportions, and lightings are elements which transpose quite well from sculpting to graphic design. This latter

statement requires empirical validation. The CST is a new theory which claims to account for the transfer of knowledge, skill, and motivation across various domains. Its predictions have not yet been empirically demonstrated. The unique combination of cognitive spaces gives each domain their unicity. Acknowledging that transfer may only occur when individuals have the metacognitive understanding of what transfer and why, and deliberately learn those skills with the intention to generalize them (Salomon & Perkins, 1989), the CST could be used as a map to point towards the type of skills and content which we may be expected to transfer across domains.

Openness to Experience and the Cognitive Spaces

Openness to experience is a personality trait which captures a tendency to explore the world perceptually and cognitively (Abuhamdeh & Csikszentmihalyi, 2012; DeYoung, 2015a). It has been robustly associated with engagement in creative activities across various domains (Feist, 1998; Kaufman et al., 2016; McCrae, 1987). It is theorized to be composed of two facets, namely *Openness*, which corresponds to an exploration of perceptual information, and *Intellect*, which corresponds to an exploration of intellectual information (DeYoung, 2015a). In line with the CST, openness to experience would correspond to a tendency to explore all ten spaces of the theory. Indeed, only an individual truly openness to experience would ascribe value to the entire range of human experiences. Interestingly, among the ten spaces of the CST, five could be described as *experiential* and five as *structural*. This is shown in Figure 2. This division fits the Openness/Intellect distinction. More specifically, the Openness subfacet would correspond to the exploration of the five experiential spaces (see Figure 2) and the Intellect subfacet would correspond to the exploration of the five structural spaces. Thus, the CST integrates the construct of Openness to experience directly into its framework, without contradicting previous findings

while also providing new areas of research and new possibilities of refinement to the measurement of that construct.

Divergent Thinking and the Cognitive Spaces

Divergent Thinking (DT) can be defined as the generation of variations or alternative solutions to a problem (J. P. Guilford, 1967). It is the mode of thinking which has received the most attention on the part of creativity researchers. In part because it encompasses many relevant thinking mechanisms, especially at the idea generation phase of the creative process.

The framework developed in this chapter assumes that creative skills, such as divergent thinking, allow us to explore the possibilities of a cognitive space (see also Boden, 2004). Hence, this framework defines divergent thinking as "the fluid navigation and exploration of a space". One hypothesis would contend that the mechanisms of DT are general and apply equivalently to all ten spaces. Another possibility is that the mechanisms of DT are specific to each space. The two possibilities are not mutually exclusive, and both could be true. To verify these hypotheses, it might be necessary to design tasks specifically tailored to each cognitive space and to investigate "space-specific" effects of DT abilities. The assumption that DT is a general mechanism has been challenged by observations that various DT tasks had only small-to-moderately correlation with one another (Runco et al., 2016). Moreover, null correlations have been observed between the verbal and figural versions of the Torrance Test for Creative Thinking (TTCT; Torrance, 1990). Despite the lack of convincing psychometric evidences, researchers usually assume that divergent thinking is a domain-general skill (Baer, 1994; Runco et al., 2016). More research is needed to unravel this question and the spaces of the CST could contribute to this line of research.

Conclusion

The framework elaborated in this chapter views creativity as a distributed process involving many people, tools, and systems. The creator is seen as one role among many others. As an example, the consumers, distribution platforms, and resource systems also have an important impact on the process of creation. The cognitive spaces of the CST can be used to have a grasp on what creativity looks like in various domains, and to identify what aspects of a product is being consumed.

A major debate within the field of creativity has been on the domain-specific vs. domain-general nature of creativity. The debate, as it goes, questions whether creative skills enable you to be creative in every activity, or whether they are dependent on specific activities. The debate is usually framed in terms of creative skills, and not relative to the creative process. Creative skills might be more or less specific depending on the skill in question. Likewise, the creative process of the creator seems quite general: in all cases, *motivation* is needed to *master* and *explore* the possibilities of one or many cognitive spaces. The content and dimensions of each space, however, are specific. Hence, a relatively general process is applied onto specific mental content.

From this chapter, one should retain that the possibilities of the mind can be mapped according to fundamental cognitive spaces. The next chapter of this thesis is devoted to the development of a questionnaire measuring the ten cognitive spaces of the CST. This questionnaire is used in Chapter 3 to study the creative activities and creative achievements of a population of university students. This thesis ends with a discussion on how to implement the CST into educational systems and it is concluded with future avenues of research.

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Appendix A

Table A1. The Ten Spaces of the Cognitive Space Theory (CST), with their Units, and their Relations with Domains.

Space	Operationalization	Examples of units	Domains of predilection
Movement	Space composed of physical or projected motions.	Directionality (forward, backward, sideways, …), speed, precision, coordination, strength, endurance	Sports, instruments playing, painting technics, magic tricks, cooking maneuver, surgical operations, e-sports, driving, …
Image	Space composed of visual experiences.	Color, light /shadow, foreground/background, shapes, lines, perspective, focus, proportions, visual angles, scenes	Painting, drawing, sculpture, photo, cinema, fashion, dance, design, architecture, marketing, ...
Sound	A space composed of auditive experiences	Volume, pitch, melodies, harmonies, tone	Music, poetry, cinema, literature, speech (including acting, teaching, coaching, social interactions).
Emotion	A space composed of affective experiences.	Pain, joy, sadness, disgust, hunger, tiredness, pride, excitement, worry, confidence, doubts	Therapy, social work, social relationships, communication, theater, acting, cinema, literature, arts, …
Sensation	A space composed of chemical sensorial experiences (taste, scent, and touch)	Fragrances, aromas, smells, flavors, taste, acidity, sweet, bitter, salty, umami, warm/cold, pressure	Cooking, perfume, sexual intercourse, massage, body care (bath, bubbles, cream, …), …
Symbol	Space composed of representations that stand for something else.	Schemas, concepts, models, icons	Language, poetry, philosophy, mathematics, marketing, engineering, computer science, science, …

System	Space composed of interconnected parts organized to achieve a function.	Parts, interdependency, functions, self-regulation, homeostasis, emergence, feedback loops	Science, grammar, mathematics, computers, robotics, engineering, design, architecture, urbanism, geometry, mechanics, construction, …
Network	A space composed of associations.	Nodes, clusters, links, distance/degree of separation, connections, weight, categories, attributes	Philosophy, poetry, language, law, journalism, science, communication, social networks, social influence, interpretation, semantic, …
Strategy	A space composed of outcomes and series of actions to achieve that outcome.	Resources, information, goals, plans, tactics, positioning, steps, optimization	Survival, army, sports, coaching, business, politics, economy, poker, management, leadership, competitive environments, games, …
Story	A space composed of an account of events.	Characters, events, problems, resolution, transitions, narratives, plots, introduction, conclusion, build up	Writing, humor, music, cinema, theater, journalism, marketing, law, teaching, science, …

Note. Domains may navigate more than one cognitive spac

Chapter 2

Validation of the Creative Exploration Questionnaire

Abstract

This study validates and establishes the psychometric properties of a new self-reported questionnaire called the *Creative Exploration Questionnaire* (CEQ). This questionnaire assesses the exploration and mastery of ten fundamental cognitive space. The cognitive spaces were defined in a recent theory, namely the Cognitive Space Theory (Chapter 1). The questionnaire can be used to understand the composition of various domains of activity. Across two studies (Study 1: n = 378 community participants from Amazon MTurk; Study 2: n = 278 Canadian university students from a participation pool) we replicated the factorial solution. All items had good primary loadings. However, we noticed some collinearity problems between the two factors composing each space, namely the mastery and exploration factors. Moreover, collinearity between some of the cognitive spaces should be monitored. We established its convergent validity towards dimensions of curiosity, creative self-ratings, competency self-ratings, domain-motivation, openness to experience, and creative self-concept. We established its divergent validity towards academic self-concept. Lastly, we demonstrated its predictive validity towards divergent thinking tasks. We discuss how the questionnaire can be used to study the composition of domains, which may contribute to research on creative potential and the transfer of knowledge, skills, and motivation across domains.

Keywords: Creativity; Self-Reported Questionnaire; Exploration; Cognitive Spaces

Chapter 2

Title: Validation of the Creative Exploration Questionnaire

Creative thinking is present in all spheres of life. Certainly, its manifestation is more obvious in some domains, such as painting or music, than in others, such as politics or management. Yet, there is no doubt that the latter domains also involve creativity. Therefore, a question of major interest is: how creativity manifests itself in various domains? What does it look like in sports, teaching, law, design, poetry, …? Recognizing creativity in any domains can help identify and support individuals who may not otherwise be recognized for their creative contributions. It can also foster people's creativity in these domains, and thus ultimately be conducive of a more dynamic and innovative society. The current study validates a self-reported questionnaire whose purpose is to map out the content of domains.

Domains are commonly defined as organized spheres of activities. Examples of domains include soccer, natation, chemistry, physics, photography, politics, and law. To identify the similarities and differences between domains, creativity researchers have mainly relied on the assumption that they could be explained by a common higher-order factor. For example, similarities in painting, drawing, and sculpting could be explained by a common 'visual arts' factor. One influential framework in the field of creativity is the Amusement Park Theory (APT; Kaufman & Baer, 2004a). This theory organizes the domains in a hierarchy of increasing specificity. At the most general level, one can find initial requirements for creative productivity. This includes intelligence, motivation, and environmental factors. At the second level, we find thematic areas, which refer to broad fields such as "arts" vs. "science". Beneath those thematic areas are the domains, such as music, dance, painting, or biology. Lastly, micro-domains represent specific tasks, activities, or technics within a domain, such as drawing vs. oil painting.

The APT is useful to bridge the general requirements of the creative process (e.g., motivation and intelligence) with mediums of increasing specificity, i.e., specific activities. However, the theory is silent regarding the content of domains. Indeed, the APT does not specify what the domains from the same thematic area have in common. For example, within the thematic area of art, one can expect the domains of music, dance, and painting (Kaufman & Baer, 2004a). These domains have something in common, but it is not said *what*. Arguably, the similarities between music and dance are not the same as the similarities between dance and painting. This limit of the APT is revealed by the use of exploratory factor analyses to study its structure instead of testing direct predictions (e.g., Carson et al., 2005; Kaufman, 2012; Kaufman & Baer, 2004; Kaufman, Cole, et al., 2009; Kaufman et al., 2009).

Studies inspired by the APT have attempted to empirically derive its structure, i.e., determining which domains should be grouped under which thematic areas. This has led to the validation of multiple questionnaires of self-reported creativity which have been used with varied populations. Most, if not all, of these questionnaires have used a data-driven approach. Typically, participants are asked to evaluate their level of creativity on various domains and a factorial structure is then extracted from the covariations amongst these self-ratings (Carson et al., 2005; J. C. Kaufman, 2012; J. C. Kaufman & Baer, 2004a). Consequently, the higher-order factors extracted from this method are defined *post hoc*. However, as relevant as exploratory structures may be, the next step is to propose theoretical justifications for these factorial solutions. The questionnaire investigated in the current study proposes such theoretical explanans.

In addition to the limit of using exploratory analyses, a second limit, which applies even when *a priori* factors are specified, is the inevitable selection of domains to be included in a questionnaire. Indeed, the almost endless number of domains in which creativity can manifest

makes it unadvisable to try to include them all. Consequently, only a subset of domains is selected. As a result, the factorial solution of any questionnaire using this approach necessarily depends upon the domains included and excluded from the list. In other words, the selection of domains determines the factorial solution, and therefore, the solution changes as the list of domains changes. For instance, a questionnaire with only artistic domains, such as music, painting, drawing, and poetry, might extract a single higher order factor. However, a second questionnaire with mathematics added to the previous list might find a two factors solution — mathematics forming one factor, and the rest of the domains forming another; or perhaps music and mathematic could load on the same factor (Vaughn, 2000), and the remaining domains on another. Add another domain and you may end up with three factors.

These limitations may account for why different questionnaires using this approach have not converged into a stable and common factorial structure. For example, the *Creativity Scale for Diverse Domains* (CSDD; Kaufman & Baer, 2004), starting with nine domains, obtained a solution with three higher order factors, namely: Empathy/Communication, Hands On, and Math/Science. The *Creative Achievement Questionnaire* (CAQ; Carson et al., 2005), starting with 10 domains, obtained a solution with three factors (Expressive, Scientific, and Performance) or a two-factor solution (Arts and Science). The *Creativity Domain Questionnaire* (CDQ; Kaufman, Cole, et al., 2009), starting with 56 domains, found seven factors: Artistic-Verbal, Artistic-Visual, Entrepreneur, Interpersonal, Math/Science, Performance, and Problem Solving. A revised version of the CDQ (Kaufman et al., 2009) reduced the number of domains to 21 and obtained a solution with four factors: Arts, Drama, Interaction and Science/Math. The most recent questionnaire in this category is the *Kaufman Domains of Creativity Scale* (K-DOCS; Kaufman, 2012), which investigates activities instead of domains (e.g., playing a musical

instrument instead of "music"). Starting with 50 activities, the latter obtained a five factors solution, namely: Every day, Scholarly, Performance, Mechanical/Scientific, and Artistic.

To arrive at a stable factorial solution, it is necessary to achieve independence from the domains themselves. Moreover, to identify commonalities across domains, a more precise theory is required.

The Cognitive Space Theory

The *Cognitive Space Theory* (CST; Chapter 1) proposes that domains allow us to explore and "navigate" the possibilities of more fundamental cognitive spaces. The theory assumes that different domains can be used to explore the same underlying space. Moreover, each domain is not reducible to only one fundamental space, but rather it usually offers a unique combination of many fundamental cognitive spaces.

The CST defines ten cognitive spaces. The ten spaces are: *sound*, *emotion*, *image*, *story*, *strategy*, *symbol*, *network*, *system*, *movement*, and *sensation*. These spaces are the building blocks of our thoughts, experiences, and activities. The ten spaces are listed and defined in Appendix A. Each cognitive space obeys the same logic. They all possess combinable "units". These units can be combined into more complex sets or broken down into smaller units. For example, the *movement* space covers basic movements such as moving forward, jumping, and running. Basic movements combine into impressive performances, such as dancing, doing a backflip, or climbing a wall. The potential combinations are almost endless.

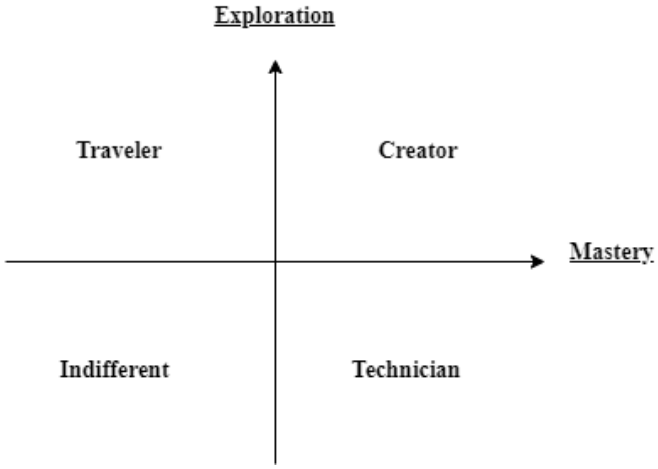
The conceptual relationship between a domain and a cognitive space is exemplified by filmmaking. Making a film requires to consider the image, the sound, the story, and the emotions. It also requires strategies to produce it. Each of those aspects correspond to a cognitive space, and reveal how creativity manifests concretely in this domain. Someone interested in

filmmaking could be creative in all or only one of those cognitive spaces. This explains why many creators cooperates to produce large-scale movies. Whenever two domains exploit the same underlying spaces, such as cinema and music exploiting sounds, this suggests plausible overlap and transfer of knowledge, skills, and motivation.

The Creative Exploration Questionnaire

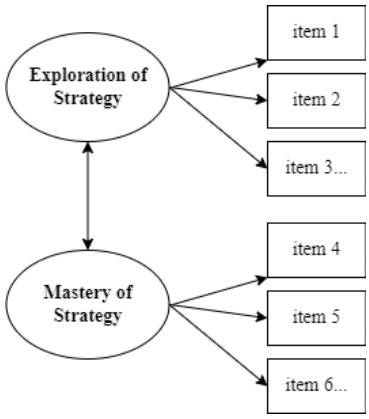
The *Creative Exploration Questionnaire* (CEQ) is a first attempt to operationalize the Cognitive Space Theory. This questionnaire aims at measuring the ten cognitive spaces of the theory with two factors, namely *mastery* and *exploration*. Thus, the questionnaire integrates a social componential model whereby *motivation*, *domain knowledge and skills*, and *creative skills* are needed to produce work deemed creative to experts eyes (Amabile, 1983). The CEQ incorporates this model by assessing mastery, which is defined as the "acquisition of domain-knowledge and technics", and exploration, defined as "seeking novelty", for each space of the Cognitive Space Theory. We labeled this model the *2×2 model of the creator*. The model is depicted in Figure 1. A schematic of the factorial structure of the CEQ is shown in Figure 2 for the strategy space.

Figure 1. The 2×2 Model of the Creator



Note. Exploration and Mastery are assessed separately for each space of the Cognitive Space Theory

Figure 2. Example of the Factorial Structure of the Creative Exploration Questionnaire (CEQ) for the Strategy Space



Note. This structure is replicated for the ten cognitive spaces assessed by the questionnaire.

The mastery and exploration factors lead to four possible profiles, depicted in Figure 1. High mastery and high exploration of a space is consistent with high creative potential in the domains which exploit that space. In contrast, being high only on the exploration axis suggests interest in improvisation, having fun, testing novel combinations, and exploring the possibilities of a space. These individuals are called *Travelers*. Being high only on mastery suggest rigor, practice, perseverance, proficiency, and control. Despite having good techniques, these individuals may lack the autonomy to propose their own original ideas and therefore are called *Technicians*. Lastly, individuals who do not explore nor master a space are mostly indifferent towards it. Thus, we labelled this last profile the *Indifferent*.

The Creative Exploration Questionnaire is meant to solve two main limitations of previous creativity questionnaire, as raised earlier. First, the CEQ defines its factors a priori. Second, the questionnaire is not based on a list of domains. Instead, it is based on ten cognitive spaces. Hence, the questionnaire can be used to understand the composition of domains, a novel contribution of this research. For example, instead of asking about creativity in music, the CEQ

asks about a tendency to explore sounds and harmonies (see Appendix B for the items). This is intended to allow poets — among others — to identify with the *sound* space and to better understand some of the reasons why people enjoy engaging in music, poetry, or cinema, for example.

Study 1

The goal of this study was to validate the Creative Exploration Questionnaire. We aimed at establishing its factorial, convergent, and predictive validity. We recruited community participants on Amazon Mechanical Turk (MTurk). Factorial validity was inspected by means of confirmatory factor analyses. The convergent and predictive validity of the questionnaire was examined with respect to dimensions of curiosity, creative self-ratings in various domains, competency self-ratings, as well as motivation in the participant's main domain of interest.

It was hypothesized that 1) the CEQ would correlate strongly with all dimensions of curiosity, 2) the CEQ would correlate strongly with creative self-ratings in the various domains, 3) the CEQ would correlate moderately with competency self-ratings, a relationship driven by the mastery factor of the CEQ, and 4) the CEQ would correlate moderately to autonomous motivation, a correlation driven by the exploration factor, whereas the mastery factor would correlate moderately with a controlled motivation.

Methodology

Participants

We retained $n = 378$ participants from the initial 684 recruited through Amazon Mechanical Turk. Participants were compensated three American dollars for their participation (15 min). Inclusion criteria were residency in United States or Canada and proficiency in English-speaking and reading. Due to resource constraints, we aimed at a sample between 300 to

400 participants. One rule of thumb of survey validation suggests that ten participants per item is needed (Nunnally & Bernstein, 1994). Because the questionnaire possesses 75 items, the needed sample size would be 750 participants. However, Monte Carlo simulation studies have found that sample sizes above $n > 200$ with three indicators per latent factor could be sufficient (see Kyriazos, 2018 for a review). Model complexity and the number of factors do impact the statistical power of factorial analyses. Hence, we tested individual CFAs for each space in order to reduce model complexity and generate trustworthy parameter estimates in the models.

Participants who completed the study in less than seven minutes were excluded. Likewise, participants who failed the attention check question were removed (*To make sure you are paying attention, please select the second answer*). These two criteria together eliminated 303 participants. Univariate outlier inspection revealed no extreme case. Multivariate outlier inspection based on Mahalanobis distance suggested three outliers which we removed ($p < .001$, $df = 5$).

Mean age was 35.9 (SD = 10.9). A majority of participants reported being male (54%) and English native speakers (98.7%). Participants identified themselves as white (87.3%), black (7.4%), Hispanic (2.4%), Asian (2.4%), or another culture (0.5%). Most participants had a college diploma (59.3%), fewer had a high-school (7.9%), master (31.0%), or doctorate (1.6%) diploma. Lastly, participants reported their family socio-economic status to be lower class (4.0%), lower-middle (11.6%), middle (52.9%), upper-middle (27.8%), or upper-class (3.4%).

Procedure

The study was conducted online. Participants answered socio-demographic questions and completed the CEQ as well as other questionnaires assessing dimensions of curiosity, their self-

reported creativity in a selected number of domains (see below), as well as their expertise in these domains.

Item development

The questionnaire has undergone many iterations before reaching the version used in this study. A bank of a hundred and eleven items was first developed based on an earlier conceptualization of the theory, consisting of seven spaces. This preliminary bank of item was tested and refined through a series of correlational studies. Three additional cognitive spaces were added to the theory and subsequently added to the questionnaire. Earlier versions of the questionnaire were promising but had important flaws. In particular, the predictive validity towards creative self-ratings in various domains was promising, but we noticed multicollinearity problems between the factors of the questionnaire ($r > .90$).

Measurement

Creative Exploration Questionnaire (CEQ). The mastery and exploration of ten cognitive spaces was assessed with the most recent version of the Creative Exploration Questionnaire, available in Appendix B. This version includes 75 items distributed across ten cognitive spaces. A description of each cognitive space is given in Table A1 of the appendix. Instructions for the CEQ were as follow: "*While answering these questions, think of all the activities that you engage in on a regular basis. This could be your work or hobbies. Read each statement and determine if it describes you. Try to see yourself as you are and not as you wish you were."* Participants rated their answer on a scale from 1 = (*Very untrue of me*) to 7 (*Very true of me*). An example item of movement mastery is: "I practice the same physical movements a lot to refine my skills."

Self-ratings of Creativity in Various Domains. Participants were asked to judge their creativity compared to people roughly their age on a list of 31 domains. The list was inspired by the *Revised Creative Domains Questionnaire* (CDQ-R; Kaufman et al., 2010). The list is available in Appendix C. There is no internal consistency coefficient because we did not aggregate the domains on higher factors. Participants rated their answer on a scale from 1 = (*Much less creative*) to 5 (*Much more creative*).

Expertise. We asked participants to select all the domains in which they had a significant interest among a list of 31 domains (the same list used for the self-ratings of creativity). Afterwards, we asked the participants to narrow their choice to only one domain with which they identified the most. We then asked the following six questions about the domain selected: 1) *how many years of your life (approximately) have you been engaged in that domain*. 2) *do you consider yourself a beginner, intermediate, intermediate-advanced, advanced, or expert/professional*. 3) *Have you learned this domain mainly through formal training, by yourself, or both equivalently?* 4) *How competent would you rate yourself in that domain compared to other people involved for as long as you in it?* 5) *How creative would you rate yourself in that domain compared to other people involved for as long as you in it?* 6) *Name one thing you find motivating about that domain.*

Motivation for the Selected Domain. We used the *Brief Motivational Regulation Measure* (BMRM; 12 items; Gaudreau, 2014) to assess *autonomous*, *controlled*, and *amotivation* motivational constructs for the domain the participants identified themselves with the most. The BMRM is an operationalization of the *Self-Determination Theory* (Deci, 1971; Deci & Ryan, 1985). The questionnaire referred to reasons why participants engaged in their main domain of interest. A composite score of autonomous motivation was computed by averaging the items of

the identified, integrated, and intrinsic subscales (6 items). A composite score of controlled motivation was computed by averaging the items of the introjected and external subscales (4 items). The subscale of amotivation was not retained considering its high correlation with the controlled motivation variable in this sample (r = .87). An example item of intrinsic motivation is "Because I truly love it." An example item of extrinsic motivation is: "Somebody is putting pressure on me". An example of amotivation is: "I do it, without really knowing why I continue." Participants answered on a scale ranging from 1 (*Not at all for this reason*) to 7 (*Totally for this reason*).

Curiosity. Curiosity was assessed with the *Five-Dimensional Curiosity Scale* (5DC; 25 items; Kashdan et al., 2018). Five dimensions of curiosity are captured by this questionnaire, namely *Joyous exploration* (i.e., seeking pleasures and novel stimuli)*, Deprivation sensitivity* (i.e., the capacity to deal with information gaps)*, Stress tolerance* (i.e., a capacity to deal with stimuli that are new, uncertain, complex, and conflict laden)*, Social curiosity* (i.e., a curiosity about other people)*, and Thrill seeking* (i.e., seeking the thrill associated with risky, new, or dangerous situations). An example item of joyous exploration is: "I view challenging situations as an opportunity to grow and learn." An example item of deprivation sensitivity is "Thinking about solutions to difficult conceptual problems can keep me awake at night". An example item of stress tolerance is: "The smallest doubt can stop me from seeking out new experiences" (reversed). An example item of thrill seeking is: "The anxiety of doing something new makes me feel excited and alive". Participants answered on a scale from 1 (*Does not describe me at all*) to 7 (*Completely describes me*).

Plan of Analyses

The factorial structure of the CEQ will be examined first. Each space was fitted in isolation from each other, instead of examining all items and all factors simultaneously. Fitting each space in isolation allows to identify problems with the items of a space without the influence of potential problems from another space. Moreover, this approach validates each space independently, hence researchers will have the option to choose the subset of spaces they desire, instead of having to use all ten every time. To test the factorial structure, a conventional Confirmatory Factor Analysis (CFA) was specified with two factors — mastery and exploration — estimated with Maximum Likelihood Robust (MLR) estimator. This model fixes all cross-loadings and all correlated-residuals to zero.

The convergent validity of the questionnaire will be examined with respect to dimensions of curiosity. The predictive validity of the CEQ will be investigated with respect to creative self-ratings in various domains. Moreover, we will investigate the distinction between the mastery and the exploration subscales of the CEQ within three subsamples based on the three most frequently selected domains of interest. In this latter analysis, the mastery and exploration factors will be used to predict motivational constructs, creative self-ratings, as well as self-ratings of competency.

Results

Preliminary Analyses

The descriptive statistics for each item of the CEQ are reported in Table 1. The mean of each item ranged from 3.7 to 5.3 on a seven points scale. Their standard deviations ranged from 1.3 to 1.8. The full range of values were used for all items (min = 1, max = 7). Lastly, all items

showed some skewness (average skew = -.072), indicating a celling effect. All skewness coefficients were below ± 1.

Factorial Structure

We tested a CFA model with two-factors —i.e., mastery and exploration— for the ten cognitive spaces fitted in isolation. The items loadings are reported in Table 1. Notably, all items loaded on their respective factor with coefficients ranging from $\lambda = .50$ to .87.

Table 1. Descriptive statistics and primary loadings for the items of the Creative Exploration Questionnaire

Spaces	Item	λ Mastery	λ Explorer	Mean Study 1	SD Study 1	Skewness Study 1	Mean Study 2	SD Study 2	Skewness Study 2
Symbol	I practice my ability to manipulate symbols and abstract representations.	.87 (.82)	-	4.77	1.777	-0.691	3.29	1.7	0.3
	I learn about specific symbols in a supervised context.	.78 (.70)	-	4.62	1.806	-0.547	3.26	1.6	0.3
	I practice my ability to work with abstract representations.	.80 (.68)	-	4.86	1.636	-0.813	3.69	1.6	-0.1
	I am working on mastering specific symbolic operations.	.83 (.80)	-	4.70	1.800	-0.646	3.01	1.6	0.3
	I often invent new symbols or concepts.	-	.86 (.72)	4.68	1.748	-0.683	3.42	1.6	0.1
	I like to invent original symbols.	-	.88 (.75)	4.66	1.742	-0.661	3.56	1.8	0.1
	I like to imagine original symbols to represent things.	-	.82(.78)	4.71	1.700	-0.699	3.15	1.7	0.4
Strategy	I practice the same strategies a lot to refine them.	.70 (.67)	-	5.03	1.467	-0.704	4.42	1.7	-0.5
	I learn about specific strategies in a supervised context.	.76 (.63)	-	4.79	1.633	-0.689	3.86	1.7	-0.3
	I'm working on mastering specific strategies.	.74 (.77)	-	4.97	1.538	-0.789	4.01	1.7	-0.3
	I often invent unusual strategies for the fun of it.	-	.74 (.73)	4.73	1.630	-0.741	3.59	1.6	0.0
	I like to think of wild strategies.	-	.78 (.83)	4.85	1.607	-0.753	3.86	1.7	-0.2
	I often think of alternative strategies.	-	.68 (.61)	5.18	1.342	-0.839	4.45	1.6	-0.6
Movement	I practice the same physical movements a lot to refine my skills.	.78 (.60)	-	4.83	1.574	-0.795	4.33	1.8	-0.3
	I learn new movements in a supervised context.	.85 (.69)	-	4.60	1.785	-0.559	3.5	1.8	0.1

Spaces	Item	λ Mastery	λ Explorer	Mean Study 1	SD Study 1	Skewness Study 1	Mean Study 2	SD Study 2	Skewness Study 2
	I'm working on mastering specific movements.	.82 (.83)	-	4.78	1.651	-0.756	3.72	1.8	0.0
	I often try unusual movements for the fun of it.	-	.71 (.65)	4.43	1.800	-0.478	3.68	1.8	0.0
	I like to think of wild movements I could do with my body or through a controller.	-	.84 (.66)	4.65	1.752	-0.668	3.41	1.8	0.2
	I often think of different ways I could achieve a specific movement, either with my body or through a controller.	-	.85 (.64)	4.72	1.672	-0.747	3.62	1.8	0.1
	I like to experiment with rhythms.	-	.78 (.55)	4.82	1.742	-0.639	3.85	1.8	-0.1
Image	I practice my ability to recognize nuances in colors.	.81 (.77)	-	4.67	1.669	-0.547	3.42	1.7	0.3
	I practice my ability to draw specific shapes.	.85 (.73)	-	4.68	1.796	-0.643	3.67	1.9	0.1
	I'm working on mastering specific visual technics.	.85 (.67)	-	4.75	1.729	-0.703	3.39	1.7	0.2
	I learn about principles of visual art in a supervised context.	.85 (.65)	-	4.62	1.743	-0.600	3.08	1.7	0.3
	I often improvise with visual materials.	-	.81 (.68)	4.84	1.659	-0.733	3.91	1.7	-0.1
	I often experiment with visual angles and point of views.	-	.83 (.72)	4.82	1.662	-0.836	3.96	1.8	-0.2
	I often explore new visual effects for the fun of it.	-	.81 (.71)	4.74	1.689	-0.617	3.76	1.7	-0.1
	I often think about the possibilities I could realize from images or visual elements.	-	.81 (.68)	4.90	1.588	-0.791	4.07	1.8	-0.2
	I often think about original combinations of shapes and colors.	-	.87 (.77)	4.78	1.729	-0.718	3.65	1.8	0.0

Spaces	Item	λ Mastery	λ Explorer	Mean Study 1	SD Study 1	Skewness Study 1	Mean Study 2	SD Study 2	Skewness Study 2
System	I practice my ability to understand how parts of a system affect the functioning of the whole system.	.79 (.69)	-	5.12	1.436	-0.894	4.06	1.7	-0.3
	I practice my ability to analyze certain types of systems (e.g., mechanical, social or physical systems).	.79 (.61)	-	5.01	1.500	-0.714	3.96	1.7	-0.2
	I learn about specific systems in a supervised context.	.77 (.62)	-	4.71	1.672	-0.652	3.5	1.7	0.1
	I have a thorough understanding of how certain systems work.	.70 (.68)	-	5.13	1.403	-0.875	4.18	1.6	-0.3
	I try to understand how all types of systems work.	-	.74 (.75)	5.13	1.386	-0.668	3.75	1.8	0.0
	I often think of alternative ways a system could be designed.	-	.75 (.70)	5.04	1.512	-0.807	3.8	1.7	-0.1
	I like to invent new systems to solve problems.	-	.81 (.74)	4.93	1.576	-0.807	3.25	1.7	0.2
	I often invent original systems which carry out a function.	-	.81 (.77)	4.68	1.731	-0.682	3.22	1.6	0.2
Story	I practice telling stories in particular genres.	.88 (.85)	-	4.67	1.753	-0.661	3.66	1.8	0.1
	I practice telling stories with specific kinds of characters.	.87 (.83)	-	4.76	1.759	-0.706	3.68	1.9	0.2
	I learn about storytelling technics in a supervised context.	.80 (.58)	-	4.63	1.801	-0.563	3.25	1.7	0.2
	I often think of alternative ways I could tell a story.	-	.79 (.71)	4.92	1.542	-0.798	4.35	1.8	-0.4
	I often improvise stories.	-	.83 (.69)	4.93	1.581	-0.879	4.31	1.7	-0.4
	I often think of original characters for a story.	-	.79 (.80)	4.87	1.662	-0.755	4.24	1.9	-0.3
Emotion	I have difficulty dealing with my	*removed*	*removed*	3.70	1.858	0.270	3.87	1.7	0.2

Spaces	Item	λ Mastery	λ Explorer	Mean Study 1	SD Study 1	Skewness Study 1	Mean Study 2	SD Study 2	Skewness Study 2
	emotions.								
	I practice my ability to identify nuanced emotional states.	.83 (.72)	-	4.91	1.524	-0.705	4.23	1.7	-0.4
	I practice my ability to be fully immersed in the present moment.	.72 (.64)	-	5.07	1.403	-0.907	4.59	1.5	-0.6
	I practice my ability to calm my emotions.	.70 (.64)	-	5.19	1.442	-0.847	4.83	1.5	-0.7
	I daydream and fantasize, with some regularity, about things and situations that might happen to me.	-	.50 (.46)	5.08	1.496	-0.912	5.38	1.7	-1.0
	I really get involved with the emotions of characters in movies and stories.	-	.61 (.59)	5.31	1.395	-0.898	5.16	1.6	-0.8
	I like to feel new emotions just for the fun of it.	-	.69 (.62)	4.76	1.673	-0.662	4.01	1.8	-0.1
	I engage a lot in emotional exploration.	-	.73 (.81)	4.91	1.562	-0.826	4.57	1.7	-0.4
	I often think of original ways to make people feel certain emotions.	-	.78 (.57)	4.86	1.626	-0.823	4.31	1.7	-0.4
Sound	I practice my ability to recognize specific sounds.	.79 (.67)	-	4.69	1.691	-0.598	3.82	1.7	-0.1
	I learn about specific sounds in a supervised context.	.82 (.72)	-	4.66	1.745	-0.624	3.3	1.7	0.2
	I try to master specific sounds.	.88 (.75)	-	4.64	1.778	-0.681	3.4	1.7	0.1
	I explore new patterns of sounds for the fun of it.	-	.84 (.82)	4.83	1.751	-0.735	3.54	1.7	0.1
	I like to think of wild possibilities I can achieve with sounds.	-	.88 (.80)	4.69	1.747	-0.673	3.27	1.7	0.3
	I often improvise with the sounds of words, objects, or musical instruments.	-	.85 (.76)	4.76	1.696	-0.723	3.72	1.8	0.1

Spaces	Item	λ Mastery	λ Explorer	Mean Study 1	SD Study 1	Skewness Study 1	Mean Study 2	SD Study 2	Skewness Study 2
	I often invent original patterns of sounds, melodies, or harmonies.	-	.88 (.76)	4.67	1.744	-0.707	3.45	1.7	0.1
Sensation	I practice my capacity to identify what I taste.	.79 (.76)	-	4.86	1.575	-0.860	3.72	1.8	0.0
	I practice my capacity to identify what I scent.	.86 (.65)	-	4.86	1.717	-0.793	3.71	1.7	-0.1
	I practice my capacity to identify the sensations I experience (e.g., touch, cold, fresh, …).	.77 (.63)	-	4.83	1.670	-0.701	3.83	1.7	-0.1
	I exercise my ability to obtain specific flavors or scents.	.82 (.81)	-	4.93	1.618	-0.761	3.34	1.8	0.3
	I learn about specific flavors or scents in a supervised context.	.80 (.67)	-	4.57	1.747	-0.573	3.15	1.7	0.3
	I learn about flavors, smells, and sensations by exploring and testing wild possibilities.	-	.73 (.73)	4.93	1.518	-0.701	3.74	1.8	0.0
	I often invent original ways to use an ingredient.	-	.82 (.76)	4.90	1.545	-0.715	3.89	1.9	-0.1
	I often think of original combinations of ingredients.	-	.76 (.85)	4.95	1.511	-0.839	3.79	1.8	0.0
	I often improvise cooking recipes.	-	.63 (.70)	5.19	1.554	-0.940	4.15	2.0	-0.2
Network	I practice my ability to notice nuances in how things are conceptually associated.	.82 (.71)	-	4.90	1.576	-0.811	4	1.7	-0.3
	I learn about certain conceptual relationships in a supervised setting.	.78 (.58)	-	4.64	1.712	-0.563	3.78	1.7	-0.1
	I learn about specific types of networks in a supervised context.	.74 (.53)	-	4.79	1.631	-0.695	3.24	1.6	0.1
	I like to think of alternative definitions for things and concepts.	-	.82 (.68)	4.98	1.578	-0.873	4.15	1.7	-0.4

Spaces	Item	λ Mastery	λ Explorer	Mean Study 1	SD Study 1	Skewness Study 1	Mean Study 2	SD Study 2	Skewness Study 2
	I like to play with the meaning of things.	-	.76 (.64)	5.07	1.477	-0.813	4.49	1.6	-0.5
	I often explore the similarities and differences between different things.	-	.75 (.71)	5.06	1.449	-0.790	4.91	1.6	-0.8
	I try to find original links between ideas and concepts.	-	.71 (.72)	5.15	1.471	-0.923	4.59	1.6	-0.5

Note. The columns λ shows the primary loadings of Study 1; the primary loadings of Study 2 are reported inside the parenthesis.

Table 2. Fit indices of Study 1 for a two factors CFA model for each of the ten spaces of the CEQ.

Two-factors Model	LL	χ^2	*p*	*df*	RMSEA	CFI	TLI	SRMR	*r* between Mastery and Exploration	Cronbach α	Single factor Model LL	2 × (LL diff.)
Symbol	-4242.454	16.82	0.207	13	0.028 [0.000, 0.061]	0.997	0.995	0.014	.963	Mastery: .89 Exploration: .88	-4248.360	11.812*
System	-4718.471	31.61*	0.035	19	0.042 [0.011, 0.067]	0.989	0.983	0.022	.989	Mastery:.84 Exploration: .86	-4718.789	0.636
Strategy	-3763.895	6.77	0.561	8	0.000 [0.000, 0.054]	1.000	1.000	0.015	.921	Mastery:.78 Exploration: .77	-3768.685	9.58*
Story	-3669.129	24.92*	0.001	8	0.075 [0.043, 0.109]	0.982	0.967	0.022	.935	Mastery:.89 Exploration: .84	-3678.426	18.594*
Network	-4271.811	46.93*	0.000	13	0.083 [0.058, 0.109]	0.961	0.937	0.032	.920	Mastery: .83 Exploration: .85	-4281.603	19.584*
Sensation	-5431.302	63.71*	0.000	26	0.062 [0.043, 0.081]	0.973	0.962	0.030	.929	Mastery: .90 Exploration: .83	-5443.964	25.324*
Image	-5249.963	35.24	0.10	26	0.031 [0.000, 0.054]	0.994	0.992	0.017	.978	Mastery: .91 Exploration: .91	-5253.529	7.132*
Sound	-4097.921	18.77*	0.130	13	0.034 [0.000, 0.066]	0.996	0.993	0.012	.994	Mastery:.87 Exploration: .92	-4098.124	0.406
Movement	-4324.294	25.13*	0.022	13	0.049 [0.018, 0.078]	0.988	0.981	0.018	.966	Mastery:.86 Exploration: .87	-4327.864	7.14*
Emotion	-4951.451	39.99*	0.003	19	0.054 [0.030, 0.077]	0.973	0.960	0.035	.975	Mastery: .79 Exploration: .80	-4952.255	1.608

Note. χ^2 = chi-square; LL = Log Likelihood; df = degrees of freedom; RMSEA = Root Mean Square Error of Approximation; CFI = Comparative Fit Index; TLI = Tucker-Lewis index; SRMR = Standardized Root Mean Squared Residual. The last column represents twice the difference between the LL of the model with two factors and the LL of the model with one factor. A significant difference in that last column suggest that the two-factor model is fitting significantly better based on the likelihood test with one degree of freedom.

The model fit indices are reported in Table 2. The fit was excellent for all ten spaces, according to conventional goodness-of-fit criteria (i.e., LL closer to zero, χ^2 closer to zero, RMSEA < .10, CFI > .90, TLI > .90, SRMR < .05, primary loadings > .40). However, the correlations between the mastery and exploration factors were excessively high in all cases (ranging from r = .92 to .99). This finding suggests multicollinearity problems and the possibility for a one-factor solution to be more optimal. We tested the difference in fit between the two- vs. one- factor solutions by comparing twice the difference in Loglikelihood between the two models, times two, on a χ^2 distribution with df = 1. The difference is reported in the last column of Table 2. A significant difference supports a better fit of the two-factor solution. As can be seen in Table 2, in most cases the two-factor solution had a significantly better fit than the one-factor solution. The internal reliability, based on Cronbach alpha's, for the mastery and the exploration factors, were also satisfying, ranging from α =.77 to .92.

In brief, the fit of a CFA model with two factors for each space was excellent despite very high intercorrelations between the exploration and mastery factors (r > .90). All items had standardized loadings above .50, the internal reliability of the exploration and mastery factors for each space was good (α > .77) with fairly similar averages and variances, however the items were all weakly skewed.

Convergent Validity

We inspected the relationships between a total score on the CEQ and dimensions of curiosity. A total score on the CEQ was significantly correlated with joyous exploration (r = .66, p < .001), deprived sensitivity (r = .44, p <.001), stress tolerance (r = .38, p < 001), social curiosity (r = .66, p < .001), and thrill seeking (r = .78, p < .001). As can be seen, the strongest association was with thrill seeking (Δr = .12, Z = -3.46, p < .001).

We inspected the correlations in-between the spaces of the CEQ. We found that all the spaces were strongly correlated to one another. The correlations ranged from $r = .75$ to .90. This indicates that the spaces were not clearly distinguishable. Hence, in the following analyses, we use a total score on the CEQ instead of specific spaces to investigate its predictive validity while avoiding multicollinearity.

We used a total score on the CEQ to predict creative self-ratings in 10 of the 31 domains assessed. We selected this subset of domains based on their frequency of appearance in other questionnaires of creativity and their broad coverages. The domains selected were: music, poetry, sports, business, visual arts, cinema, teaching/coaching, mathematics, cooking, management, and research/science. The correlations are reported in Table 3. The CEQ was significantly associated with all ten domains, with correlations ranging from $r = .42$ to .60 ($p < .01$). This indicates that a total score on the CEQ predicts creative self-ratings in various domains.

In the following analysis, we investigated three subsamples of participants based on the three most popular domains they identified with. The most popular domains were music ($n = 105$), computer science ($n = 34$), and cooking ($n = 33$). These analyses focused on the factors of mastery and exploration in predicting self-ratings of creativity, competency, and motivation, relative to other individuals also involved in these domains of interest. However, we notice collinearity problems between the mastery and exploration factors. More specifically, among the subsample which selected music, the correlation between mastery and exploration for the *sound* space was $r = .75$, $p < .001$. Correlations coefficients of similar sizes were observed among the subsample of computer science for the *system* space ($r = .81$, $p < .001$) and the subsample of cooking for the *sensation* space ($r = .73$, $p < .001$). Hence, due to collinearity between the mastery and exploration factors, we investigated a total score on the CEQ and retained the entire

sample in the analyses. The results of simple correlations are reported in Table 4. The CEQ was significantly associated with creative self-ratings, competency self-ratings, as well as autonomous and controlled domain-motivation.

Table 3. Correlations Between a Total Score on the CEQ and Creative Self-Ratings in Ten Domains of Activities.

	Music	Poetry	Sports	Business	Visual arts	Cinema	Mathematics	Cooking	Management	Research/Science
CEQ	.56**	.57**	.54	.55**	.64**	.60**	.55**	.42**	.60**	.53**

Note. *$p < .05$, **$p < .001$.

Table 4. Correlations Between a Total Score on the CEQ and Domain Creative Self-Ratings, Domain Competency Self-Ratings, and Domain Motivational Constructs.

	Creative self-ratings compared to others involved in the domain	Competency self-ratings in compared to others involved in the domain	Autonomous motivation in the domain	Controlled motivation in the domain
CEQ	.47**	.38**	.43**	.61**

Note. *$p < .05$, **$p < 01$.

Discussion

This first study investigated the factorial structure of the CEQ and its convergent and predictive validity. In particular, the fit of a two-factor CFA was excellent for all ten spaces of the questionnaire, despite very high intercorrelations between the mastery and exploration factors ($r > .90$). Nonetheless, all items had loadings above $\lambda > .50$ on their primary factors. A total score on the CEQ was positively associated with all dimensions of curiosity, in particular thrill seeking, as well as with creative self-ratings in ten different domains, competency self-ratings, autonomous domain-motivation, and controlled domain-motivation.

We found some problems with the CEQ in this population. In particular, skewness was found in all items. However, as will be seen in Study 2, this problem did not occur in a population of university students without any modifications to the items. Moreover, multicollinearity between the mastery and exploration factors of each space and multicollinearity between all ten spaces in relation to each other were observed. This indicates that participants answered all questions of the CEQ in a very predictive manner. For example, participants did not really distinguished questions such as “I learn about specific systems in a supervised context” and “I often improvise cooking recipes.” As will be seen in Study 2, the multicollinearity problem regarding the cognitive spaces were attenuated without changing the items of the questionnaire. This population’ suspicious behaviors are discussed in the general discussion.

Study 2

This second study aimed at replicating the factorial structure of the questionnaire with a population of university students and further examine its convergent, divergent, and predictive validity. Participants filled questionnaires assessing their openness to experience, creative self-

concept, academic self-concept, and completed tests of divergent thinking and associative fluency abilities.

It was hypothesized that 1) the CEQ would correlate strongly with openness to experience and creative self-concept, 2) the CEQ would correlate weakly with academic self-concept, 3) the Emotion space of the CEQ, as well as the System space of the CEQ, would correlate weakly-to-moderately with DT abilities.

Participants

A sample of $n = 278$ undergraduate students from a bilingual public Canadian university in the province of Ontario was retained for analysis from the initial 325. We removed 32 participants who completed less than 60% of the study. An additional ten participants were removed after failing the attention check question. Univariate inspection ($Z > +/- 3.5$) revealed four extreme cases which we removed. Multivariate outliers' inspections revealed one extreme case which got removed (Mahalanobis distance $\chi^2 (8)$, $p < .001$). The final sample is $n = 278$. Similarly to Study 1, we aimed at a sample between 300 and 400 participants. Considering that we tested individual CFAs for each space, a sample of $n > 200$ is considered sufficient with three indicators per latent factors and good reliability (Kyriazos, 2018).

Mean age was 19.6 years old (SD = 3.6, ranging from 17 to 52 years old). A majority of participants reported being woman (70%) and English native speakers (51.6%). Some participants were French native speakers (23.0%) or other languages (25.4%). Participants identified themselves as White (39.0%), Asian (22.7%), Black (16.7%), Hispanic (2.1%), or another culture (3.9%). Participants were in their first year of college (67.1%), second (22.6%), third (6.4%), fourth (2.8%), or more (1.1%). Their programs of study were: social sciences (35.1%), health sciences (20.9%), natural sciences (10.6%), management (9.6%), biomedicine

(6%), arts (5.7%), computer science (3.2%), or others (8.9%). Lastly, participants reported their family socio-economic status as being lower class (4.6%), lower-middle (9.6%), middle (47.2%), upper-middle (35.8%), or upper-class (2.8%). Participants received one point toward their introductory psychology course for their participation.

Procedure

The study was conducted online. Participants answered socio-demographic questions and completed the CEQ as well as questionnaires assessing their openness to experience, creative and academic self-concepts, divergent and associative thinking abilities, as well as other questionnaires unrelated to the purpose of this study (see Goulet-Pelletier & Cousineau, *In preparation*, for the results of the remaining measurements). The whole procedure took about 40 min to complete.

Measurements

Creative Exploration Questionnaire (CEQ). The CEQ was assessed in the same way as in Study 1.

Openness to Experience. The personality trait openness to experience was assessed via the Big Five Aspect scale (20 items; DeYoung et al., 2007). Openness to experience is defined as an intellectual curiosity, an enjoyment of aesthetics, a sensitivity to arts, a great imagination, and non-conforming tendencies. An example item is "I see beauty in things that others might not notice." Participants answer on a 5-points scale ranging from 1 (very inaccurate) to 5 (very accurate).

Creative and Academic Self-Concept. Creative self-concept and Academic self-concept were assessed with six of the eleven items of the *Short Scale of Creative Self* (Karwowski, 2012; $\alpha = .76$) and six items ($\alpha = .87$) adapted for this study to assess academic self-concept. The list of

items is given in Appendix D. These items allowed measuring both concepts simultaneously in an efficient manner. Participants answered on a 5-points scale ranging from 1 (*very inaccurate*) to 5 (*very accurate*). An example item for creative self-concept is "*My creativity is important to who I am*". An example item for academic self-concept is "*Doing great at school is important to who I am*".

Divergent Thinking. Participants were instructed to come up with as many creative answers as they could to the following two traditional items as well as two emotional items: 1) *Tell us all the different ways you could use a brick*, 2) *Name all the things you can think of that make noise* (Wallach & Kogan, 1965), 3) *Name all the things you can think of that can be frustrating*, and 4) *Name all the things you can think of that can affect positively or negatively your self-esteem*. Participants were allotted three minutes per item. The originality of answers was evaluated by two judges based on the snapshot scoring method of Silvia and colleagues (2009). A single rating of originality was given to the set of responses of each participant. Two graduate students judged the originality of answers according to the guidelines of Silvia et al., (2008), whereby answers that are uncommon, remote, or clever are given higher score, on a scale from 1 (*not creative at all*) to 5 (*highly creative*). An average score of originality was obtained from the traditional items (i.e., average of brick and sounds items; $\alpha = .81$) and one score was obtained from the emotional items (i.e., average of the "frustration" and "self-esteem" items; $\alpha = .80$). Two average scores of *fluency* were also computed by summing and then averaging the number of answers provided to the traditional items ($\alpha = .87$) and the emotional items ($\alpha = .86$).

Associative Fluency. Participants were required to generate as many associated words as possible starting from a given word, with the only rule that each new answer must be associated with at least the previous one (e.g., book: "paper, sand, castle, …; adapted from Benedek et al.,

2012). Participants completed two trials of one minute each. The starting words were 1) disease (the study was conducted before the COVID-19 pandemic) and 2) mountain. A score of associative fluency was computed by averaging the number of responses generated on both trials ($\alpha = .80$).

Plan of Analyses

The factorial structure of the CEQ will be examined first. Its convergent validity is examined with respect to openness to experience and creative self-concept. Its divergent validity is examined with respect to academic self-concept. Lastly, its predictive validity is investigated with respect to divergent thinking abilities and associative fluency abilities.

Replication of the Factorial Structure

We specified the same CFA model with two factors, mastery and exploration, for the ten cognitive spaces fitted in isolation. The items loadings and descriptives are reported in Table 1. Similar to Study 1, all items loaded on their respective factors with standardized coefficients ranging from $\lambda = .53$ to 85 (inside the parenthesis of the λ column in Table 1).

The model fit indices are reported in Table 5. The fit was excellent for all ten spaces, according to conventional goodness-of-fit criteria. Similar to Study 1, the correlations between the mastery and exploration factors remained excessively high in all cases (ranging from $r = .78$ to .99). We tested the difference in fit between the two- vs. one- factor solutions. The difference is reported in the last column of Table 5. Similar to Sutdy 1, in most cases, the two-factors solution had a significantly better fit; except for the system, image, and emotion spaces, for which the one-factor solution was statistically equivalent. The internal reliability, based on Cronbach alpha's, for the mastery and exploration factors were similar to Study 1, except for the

network space (range was α =.66 to .84). The lowest alpha corresponds to the mastery factor of the network space.

Table 5. Fit indices of Study 2 for a two factors CFA model for each of the ten spaces of the CEQ

Two-factors Model	LL	χ^2	*p*	*df*	RMSEA	CFI	TLI	SRMR	*r* between Mastery and Exploration	Cronbach α	Single factor Model LL	2 × LL diff.
Symbol	-3292.65	25.54*	.02	13	0.06 [0.02, 0.09]	0.98	0.97	0.03	.96	Mastery = .84 Exploration = .80	-3294.01	2.726
System	-3926.02	25.90	.13	19	0.05 [0.00, 0.07]	0.99	0.98	0.03	.93	Mastery = .75 Exploration = .83	-3929.24	6.446*
Strategy	-2957.16	19.27*	.01	8	0.07 [0.03, 0.11]	0.97	0.94	0.04	.78	Mastery = .73 Exploration = .76	-2972.99	31.652*
Story	-2981.93	23.58*	.002	8	0.08 [0.05, 0.12]	0.97	0.95	0.03	.92	Mastery = .80 Exploration = .79	-2987.12	10.37*
Network	-3483.58	39.42*	<.001	13	0.09 [0.06, 0.12]	0.93	0.89	0.05	.81	Mastery = .66 Exploration = .78	-3491.77	16.39*
Sensation	-4487.76	93.64*	<.001	26	0.10 [0.08, 0.12]	0.92	0.89	0.06	.84	Mastery = .83 Exploration = .84	-4510.16	44.804*
Image	-4442.01	35.13	.12	26	0.04 [0.00, 0.06]	0.99	0.98	0.03	.99	Mastery = .79 Exploration = .84	-4442.02	0.01
Sound	-3385.53	27.34*	.01	13	0.06 [0.03, 0.10]	0.98	0.96	0.03	.96	Mastery = .75 Exploration = .86	-3386.81	2.576
Movement	-3663.12	27.26*	0.01	13	0.06 [0.03, 0.10]	0.97	0.94	0.04	.83	Mastery = .75 Exploration = .72	-3672.75	19.246*
Emotion	-3985.00	45.38*	<.001	19	0.07 [0.04, 0.10]	0.95	0.92	0.04	.96	Mastery = .71 Exploration = .75	-3985.70	1.4

Note. LL = Log Likelihood; The last column represents the difference between the LL of the model with two factors and the LL of the model with one factor multiplied by two. A significant difference in the last column suggests a significantly better fit of the two-factor model.

Convergent and Divergent Validity

We examined the ten spaces of the CEQ in relation to each other. The range of correlations was $r = .44$ to .80. The average correlation was $r = .61$ (SD = .09). Hence, the average correlation is high, and collinearity should be monitored, however this problem does not generalize to all instances. In particular, the highest correlations were between the network, strategy, system, and symbol spaces.

The correlation matrix for the main variables is reported in Table 6. A total score on the CEQ correlated positively and significantly with openness to experience ($r = .34$, $p < .001$) and creative self-concept ($r = .37$, $p < .001$). The divergent validity of the CEQ was examined with respect to academic self-concept. The correlation between a total score on the CEQ and academic self-concept was $r = .21$ ($p < .001$). These results suggest that the CEQ is associated with openness to experience and creative self-concept more so than with academic self-concept ($\Delta r = .19$, $z = 2.47$, $n = 278$, $p = .01$). In comparison, the correlation between openness to experience and academic self-concept was $r = .40$, $p < .001$ and the correlation between creative self-concept and academic self-concept was $r = .41$, $p < .001$ (see Table 8). The correlation between openness to experience and creative self-concept was larger ($r = .62$, $p < .001$).

Predictive Validity Towards Divergent and Associative Thinking

The predictive validity of the questionnaire was investigated with respect to divergent thinking and associative abilities using multivariate multiple regression models (i.e., a regression model with many predictors and many dependant variables). We selected two cognitive spaces from the CEQ to include in the model, namely the *system* and *emotion* spaces. The system space was relevant to traditional DT items, which involved the generation of alternative uses for a brick and things that make noise. Considering that these prompts call for interchanging *parts* and

functions, the system space was deemed suitable. The emotion space was relevant to the emotional DT items, considering their overlapping theme (i.e., *name things that can be frustrating* and *things that can affect your self-esteem*). Lastly, we added openness to experience to the model to evaluate the robustness of the results and the incremental predictive validity over and above openness to experience. The results are reported in Table 7.

The results for the divergent thinking tasks indicate that the emotion space of the CEQ was significantly and positively associated with all the divergent thinking scores (β ranged from .16 to .28, $p < .05$), but not towards associative fluency ($\beta = .06$, $p > .05$). Next, the system space was significantly and negatively associated with the two DT originality scores (β = -.21 and -.26, $p < .01$), but not with the two DT fluency scores, nor with the associative fluency score. Lastly, openness to experience was significantly associated with the emotional DT tasks only (β = .09 and .14, $p < .05$).

Overall, the emotion space was a reliable positive predictor of DT abilities, whereas openness to experience was a weak positive predictor of the emotional DT tasks only.

Table 6. Correlational Matrix for the Main Variables of Study 2

Variables	CEQ Emotion	CEQ System	CEQ Total	Openness to Experience	Creative Self-Concept	Academic Self-Concept	Traditional DT - Originality	Emotional DT - Originality	Traditional DT - Fluency	Emotional DT - Fluency
CEQ Emotion	-									
CEQ System	.46**	-								
CEQ Total	.69**	.82**	-							
Openness to experience	.53**	.19**	.34**	-						
Creative Self-Concept	.38**	.27**	.37**	.62**	-					
Academic Self-Concept	.27**	.19**	.21**	.39**	.41**	-				
Traditional DT Originality	.27**	.03	.06	.23**	.16**	.24**	-			
Emotional DT Originality	.27**	-.08	.14*	.21**	.21**	.10	.65**	-		
Traditional DT Fluency	.24**	.09	-.02	.27**	.16**	.18**	.63**	.41**	-	
Emotional DT Fluency	.34**	.14*	.20**	.27**	.21**	.14*	.50**	.74**	.36**	-
Associative Fluency	.13*	.05	.05	.16**	.08	.07	.46**	.50**	.40**	.48**

Note. *$p < .05$; **$p < .01$. DT = Divergent Thinking. Traditional = the brick and noise divergent thinking questions. Originality is a creativity score subjectively determined by two judges. Fluency is the number of answers provided.

Table 7. Multivariate Multiple Regression Model Predicting Divergent Thinking and Associative Fluency Abilities

	DT Originality traditional	DT Fluency traditional	DT Originality emotion	DT Fluency emotion	Associative fluency
CEQ Emotion	.25**	.16*	.24**	.28**	.06
CEQ System	-.21**	.04	-.26**	-.03	.03
Openness to Experience	.07	.11	.09*	.14*	.11
R^2	7.8%**	6.7**	8.8%**	13.4%**	2.4%

Note. All the predictors and dependant variables were entered simultaneously in the model. Estimator is MLR. $n = 278$.

Discussion

This study examined the factorial, convergent, divergent, and predictive validity of the CEQ. We found that the fit of a two-factor CFA model successfully replicated in this second study with a population of university students. All items were normally distributed, contrarily to the results of Study 1. However, collinearity between the mastery and exploration factors remained problematic in this study. Nevertheless, previous collinearity problems between the ten spaces of the CEQ were attenuated in the current study. Collinearity between the network, system, symbol, and strategy spaces should be monitored in future research using this tool.

A total score on the CEQ was moderately associated with openness to experience and creative self-concept. A weaker correlation was observed with academic self-concept. These findings support the convergent and divergent validity of the CEQ. However, we did expect a stronger correlation between a total score on the CEQ and openness to experience, due to considerable conceptual overlap. Indeed, openness to experience captures a tendency to explore the world cognitively and perceptually (DeYoung, 2015a; Oleynick et al., 2017). People truly open to experiences should ascribe value to the exploration of all the possibilities of the mind, and thus all ten spaces of the CEQ. One reason for this moderate correlation between the CEQ and openness to experience might be an operationalization of openness to experience which is focused on emotional and intellectual fantasy — at the expense of the other human's experiences. For example, exploratory analyses suggest that the association between the *emotion* space and openness to experience is stronger (r = 53) than between the *system* space and openness to experience (r = .19). The conceptual and empirical relationship between the construct of openness to experience and the cognitive spaces deserve further attention from the research community. We return to this point in the general discussion.

The *emotion* space of the CEQ was a reliable positive predictor of DT abilities over and above the construct of openness to experience. Openness to experience only significantly predicted the emotional DT tasks. Previous studies had found that openness to experience predicted traditional divergent thinking abilities (Goulet-Pelletier et al., *in revision*; McCrae, 1987). Openness to experience captures a sensitivity to emotions and an intellectual curiosity. Therefore, including this construct simultaneously with the emotion space may reduce its predictive ability towards DT. The role of emotions and moods during creative thinking has been investigated by many authors (Ashby et al., 1999; Baas et al., 2008; Davis, 2009; Goulet-Pelletier et al., *In preparation*). Notably, a recent study found that empathy predicted the same divergent thinking task used in this study over and above openness to experience (Goulet-Pelletier et al., *In preparation*). Therefore, it is plausible that the link between openness to experience and DT could be explained by the relationship between the emotion space and DT abilities. In particular, empathic abilities have been said to rely on similar imaginative and cognitive abilities than creative thinking (Anderson, 2020; Benedek et al., 2023). In another vein, we expected the *system* space to positively predict divergent thinking, because one must think in terms of functions and parts of a system while thinking of alternative uses for an object. However, we observed a negative association between the system space and the originality scores of the traditional and the emotional tasks. It is plausible that controlling for the emotional space left only a rigidity of thinking from the system space, which sometimes characterize system thinkers. For example, a meta-analysis found that scientists tended to be more conventional, rigid, and conscientious than non-scientists (Feist, 1998). This profile of low emotional expressivity and high system thinking also characterizes engineer and mathematicians.

These speculations require more studies to investigate the relationships between the *system* space, emotional rigidity, and divergent thinking abilities.

General Discussion

The Creative Exploration Questionnaire is a first attempt to operationalize the Cognitive Space Theory. The questionnaire assesses a creative potential in various domains through the mastery and exploration of ten fundamental cognitive spaces. The structure of the CEQ with the its two factors per space had excellent fit within a sample of MTurk workers and replicated in a sample of university students. However, the two factors, i.e., exploration and mastery, were too highly correlated to be differentiated in regression analyses. Each cognitive space was validated independently, hence allowing researchers to select only the subset of spaces they are most interested in.

In Study 1, we observed that all items were weakly skewed, and the ten spaces were highly correlated with one another. The skewness problem was resolved, and the collinearity between the spaces was attenuated in Study 2 without modifying the items. It is possible that the asymmetry was caused by the MTurk sample being older, and therefore would possess more experience with each space assessed. This being said, the reliability of MTurk participants is questionable (e.g., Aguinis et al., 2021). MTurk participants from Study 1 seem to have answered most questions of the questionnaire irrespectively of their content. To fully assess the validity and predictive power of the CEQ, a similar study should be conducted with a more reliable population of amateur or professional creators.

The convergent, divergent, and predictive validity of the CEQ was supported across the two studies. More specifically, the CEQ was strongly associated with dimensions of curios, as well as moderately associated with openness to experience and creative self-concept. The

association between the CEQ and academic self-concept was lower than towards creative self-concept. Moreover, the *emotion* space was a robust predictor of divergent thinking over and above openness to experience. This finding is consistent with the positive role that emotions, moods, and empathic abilities tend to play towards creative thinking (Ashby et al., 1999; Baas et al., 2008; Davis, 2009; Goulet-Pelletier et al., *In preparation*).

Using the CEQ to Inspect Domains of Creativity

The Creative Exploration Questionnaire solves the main limitations of previous creativity questionnaire. First, it is not based on a list of domains, therefore its factorial structure is confirmatory. Second, the CEQ can be used to understand the composition of domains of activities. For example, creativity in music can be understood as the exploration of sounds. Instrument playing, however, call upon the *movement* space. Studies can be designed to evaluate the relationships between the cognitive spaces and the content of various domains.

The mastery and exploration factors of the CEQ capture four different profiles, based on the 2 × 2 model of the creator (see Figure 1). Currently, the mastery and exploration factors were too highly correlated to discern their unique predictive power. The conceptual and operational distinction between exploring a space and mastering it is theoretically justified by social-cognitive theories of creativity (e.g., Amabile, 1983). Therefore, new iterations of the questionnaire should aim to resolve this issue. The wordings of the items appear not particularly problematic, although there is room for improvement (an example item for movement mastery is “I learn new movements in a supervised context”; an example item for movement exploration is “I often try unusual movements for the fun of it”). An important step for future studies would be to investigate the distinction between the exploration and mastery factors with populations of experts. It is more likely that experts find the difference between these two constructs more

meaningful than amateurs, considering that they understand their domain better, they know their own learning style, and they can grasp the distinction between improvisation and standard practice more accurately.

Conclusion and Limits

The Cognitive Space Theory proposes a novel way to think about the content of domains. The questionnaire developed in this study offers a parsimonious way to assess one's creative potential in multiple domains based on the exploration and mastery of ten fundamental cognitive spaces. The CEQ can be used to better understand the content of domains, which may contribute to research on the transfer of knowledge, skills, and motivation across domains.

An important limit of the current investigation is the lack criterion validity as well as test-retest reliability. Considering that the CEQ claims to predict a creative potential in multiple domains, demonstrating that experienced creators do in fact score higher on the relevant cognitive spaces is crucial. Attempts to establish criterion validity should be undertaken in the future to fully validate the questionnaire. Qualitative studies with experts would also be needed to support the construct validity of each space. Moreover, potential difficulties in predicting some domains over others could suggest imbalance in the cognitive spaces and therefore modification to the theory or to the items of the CEQ. The complexity of the factorial structure of the CEQ requires a large sample size to validate. In the current study, we opted for testing each space in isolation. This is an important limitation. Validating the 20-factors structure of the questionnaire would have strengthen the empirical support of the theory. Given the analyses conducted, it is impossible to be certain that each space is absolutely needed. Nonetheless, decisions to reduce or increase the list of cognitive space should be justified *theoretically* and not strictly empirically driven.

Another limit pertains to the high correlations between the mastery and exploration factors. This suggests room for improvement. The two scores are currently highly redundant. This seems to contradict the 2 x 2 model of the creator. This being said, the 2 x 2 model is an elegant model which points towards different learning styles (oriented towards copying methods vs. oriented towards the discovery of those methods by oneself). The model also juxtaposes very well with the two criteria used in the definition of a creative product, namely the novelty and usefulness criteria; whereby novelty correspond to exploration, and usefulness corresponds to mastery. Lastly, the model elegantly captures the necessity of domain-knowledge (a.k.a. mastery) and creative abilities (a.k.a. exploration) in the creative process. Considering that both, mastery and exploration, are conducive of creative potential — like two faces of the same coin —, they should remain part of the CEQ as it aim to assess one's *creative potential*, despite their high intercorrelation.

The current study makes an important contribution by proposing a first operationalization of the Cognitive Space Theory, namely the CEQ. The questionnaire was useful to predict creative self-ratings in various domains and the prediction of divergent thinking scores offered additional evidence of the usefulness of the CEQ to predict creative abilities. More studies are needed to demonstrate that each space offers unique prediction regarding specific domains. Overall, more studies are needed to investigate the relationship between the spaces of the CEQ, openness to experience, and various DT tasks.

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Appendix A

Table A1. The Ten Spaces of the Cognitive Space Theory (CST), with their Units, and their Relations with Domains.

Space	Operationalization	Examples of units	Domains of predilection
Movement	Space composed of physical or projected motions.	Directionality (forward, backward, sideways, …), speed, precision, coordination, strength, endurance	Sports, instruments playing, painting technics, magic tricks, cooking maneuver, surgical operations, e-sports, driving, …
Image	Space composed of visual experiences.	Color, light /shadow, foreground/background, shapes, lines, perspective, focus, proportions, visual angles, scenes	Painting, drawing, sculpture, photo, cinema, fashion, dance, design, architecture, marketing, ...
Sound	A space composed of auditive experiences	Volume, pitch, melodies, harmonies, tone	Music, poetry, cinema, literature, speech (including acting, teaching, coaching, social interactions).
Emotion	A space composed of affective experiences.	Pain, joy, sadness, disgust, hunger, tiredness, pride, excitement, worry, confidence, doubts	Therapy, social work, social relationships, communication, theater, acting, cinema, literature, arts, …
Sensation	A space composed of chemical sensorial experiences (taste, scent, and touch)	Fragrances, aromas, smells, flavors, taste, acidity, sweet, bitter, salty, umami, warm/cold, pressure	Cooking, perfume, sexual intercourse, massage, body care (bath, bubbles, cream, …), …
Symbol	Space composed of representations that stand for something else.	Schemas, concepts, models, icons	Language, poetry, philosophy, mathematics, marketing, engineering, computer science, science, …

System	Space composed of interconnected parts organized to achieve a function.	Parts, interdependency, functions, self-regulation, homeostasis, emergence, feedback loops	Science, grammar, mathematics, computers, robotics, engineering, design, architecture, urbanism, geometry, mechanics, construction, …
Network	A space composed of associations.	Nodes, clusters, links, distance/degree of separation, connections, weight, categories, attributes	Philosophy, poetry, language, law, journalism, science, communication, social networks, social influence, interpretation, semantic, …
Strategy	A space composed of outcomes and series of actions to achieve that outcome.	Resources, information, goals, plans, tactics, positioning, steps, optimization	Survival, army, sports, coaching, business, politics, economy, poker, management, leadership, competitive environments, games, …
Story	A space composed of an account of events.	Characters, events, problems, resolution, transitions, narratives, plots, introduction, conclusion, build up	Writing, humor, music, cinema, theater, journalism, marketing, law, teaching, science, …

Note. Domains may navigate more than one cognitive space.

Appendix B

The Creative Space Questionnaire (CEQ) V9

The CEQ assesses ten spaces (i.e., 75 items in total). Each space is assessed with three to six *exploration* questions and three to six *mastery* questions. Acknowledging that 75 questions is a lot, the factorial structure of each space was validated separately. This allows to use a single space or any number of spaces if desired. A global score on the CEQ captures a tendency to explore and master the possibilities of the mind.

Instruction: While answering these questions, think of all the activities that you engage in on a regular basis. This could be your work or hobbies. Read each statement and determine if it describes you. Try to see yourself as you are and not as you wish you were.

Very untrue of me	***Untrue of me***	***Somewhat untrue of me***	***Neither true nor untrue***	***Somewhat true of me***	***True of me***	***Very true of me***
1	2	3	4	5	6	7

Conceptual space	**Exploration**	**Mastery**
Symbol	I often invent new symbols, concepts, or operations to tackle problems. I like to think of original symbols for expressing ideas. I like to invent new symbols for the fun of it.	I practice my ability to manipulate symbols and abstract representations. I learn about specific symbols in a supervised context. I practice my ability to work with abstract representations. I am working on mastering specific symbolic operations.
Strategy	I often invent unusual strategies for the fun of it. I like to think of wild strategies. I often think of alternative strategies.	I practice the same strategies a lot to refine them. I learn about new strategies in a supervised context. I'm working on mastering specific strategies.

Conceptual space	Exploration	Mastery
Movement	I often try unusual movements for the fun of it I like to think of wild movements I could possibly do with my body or through a controller. I often think of alternative ways I could achieve a physical movement (including projected movements through a controller, a vehicle, or any intermediary). I like to experiment with rhythms.	I practice the same physical movements a lot to refine my skills. I learn new movements in a supervised context. I'm working on mastering specific movements.
Image	I often improvise with visual materials. I often experiment with visual angles and point of views. I often explore new visual effects for the fun of it. I often think of various possibilities that I could achieve with images or visual elements. I often think of alternative shapes and colors.	I practice my ability to recognize nuanced colors. I practice my ability to draw specific shapes. I'm working on mastering specific visual technics. I learn about principles of visual art in a supervised context.
System	I try to master the workings of any type of system. I often think of alternative ways a system could be designed. I like to invent new systems for the fun of it. I often invent original systems to carry out a function.	I practice my ability to understand how parts of a system affect the functioning of the whole system. I practice my ability to analyze mechanical or social systems. I learn about specific systems in a supervised context. I have a thorough understanding of how certain systems work.
Story	I often think of alternative ways I could tell a story. I often improvise stories. I often think of original characters for a story.	I practice telling stories in particular genres. I practice telling stories with specific kinds of characters. I learn about storytelling technics in a supervised context.
Emotion	I daydream and fantasize, with some regularity, about things and situations that might happen to me. I really get involved with the feelings of	I have difficulty dealing with my emotions. (R)* I practice my ability to identify nuanced emotional states. I practice my ability to be fully immersed in the present moment. I practice my ability to calm my emotions.

Conceptual space	Exploration	Mastery
	characters in movies. I like to feel different emotions just for the fun of it. I engage a lot in emotional exploration. I often think of original ways to make people feel certain emotions.	
Sound	I explore new patterns of sounds for the fun of it. I like to think of wild possibilities I can achieve with sounds. I often improvise with the sounds of words, objects, or musical instruments. I often invent original patterns of sounds, melodies, or harmonies.	I practice my ability to recognize specific sounds. I learn about specific sounds and harmonies in a supervised context. I try to master specific sounds.
Sensation	I learn about flavors, smells, and sensations by exploring and testing wild possibilities. I often play around with ingredients for the fun of it. I often think of original combinations of ingredients. I often improvise cooking recipes.	I practice my capacity to identify what I taste. I practice my capacity to identify what I scent. I practice my capacity to identify the sensations I experience (e.g., touch, cold, fresh, …). I practice my ability to achieve specific flavors or scents. I learn about specific flavors or scents in a supervised context.
Network	I like to play with the meaning of things. I often explore how things are related to each other. I often try to find original links between ideas and concepts.	I practice my ability to notice nuances in how things are conceptually associated. I learn about certain conceptual relationships in a supervised context. I learn about specific types of networks in a supervised context. I like to think of alternative definitions for things and concepts.

*This item was removed from the final questionnaire.

Appendix C

Creative self-ratings in 31 domains

Instructions: Compared to other people, how creative would you rate yourself in...

Much less creative	Less creative	Neither less nor more creative	More creative	Much more creative
1	2	3	4	5

List of domains: Music, Lit, Writing/Literature, Poetry, Video making, Research/Science, Cinema, Visual arts (including drawing, photo, sculpture, painting, and others), Fashion, Sports, Dramatic arts/Acting, Humor/Comedy, Engineering, Construction, Business, Customer service, Cooking, Design/Architecture/Urbanism, Computer science/Technology, Mathematics, Management, Teaching/Coaching, Military tactics, Politics, Philosophy, Diplomatic relations, Strategic games, Law, Social work/Therapy, Marketing, Journalism, Competitive video games (e-sports).

Appendix D

Creative Self-Concept (Karwowski, 2012; current item 1-6) and Academic Self-Concept (current item 7-12).

Definitely not	Somewhat not	Neither true nor false	Somewhat yes	Definitely yes
1	2	3	4	5

Instruction: Read each statement carefully and rate the extent to which it corresponds to you.

1. I think I am a creative person.
2. My creativity is important to who I am.
3. I trust my creative abilities.
4. I am sure I can deal with problems requiring creative thinking.
5. I am good at proposing original solutions to problems.
6. Ingenuity is a characteristic which is important to me.
7. Doing great at school is important to who I am.
8. I trust my intellectual abilities.
9. I am certain I can figure out how to do the most difficult class work.
10. If I try hard enough, I can achieve the academic goals I desire.
11. Being a student is an important aspect of myself.
12. School is an important part of my identity.

Chapter 3

Cognitive Spaces and Fluency Abilities Predict Domain-Specific Creative Achievements

Abstract

Individuals who engage in creative activities and make actual creative accomplishments are often well equipped to navigate the complexity of life, as they develop the skills necessary for adaptive and flexible thinking. As such, promoting creativity and supporting individuals' engagement in creative activities can have wide-ranging benefits for individuals and the society. The aim of the current study was to understand the factors that predict an engagement in creative activities and actual creative achievements from a population of university students. We hypothesized that the exploration of fundamental cognitive spaces, the trait openness to experience, as well as divergent and associative thinking abilities would be conducive of creative activities and achievements in a variety of domains. A second goal of this study was to examine domain-specific effects of divergent thinking abilities. We relied on the Creative Exploration Questionnaire to assess the cognitive spaces, the Inventory of Creative Activities and Achievements (ICAA) to assess eight domains of creativity, and four divergent thinking tasks as well as one associative task to investigate our hypotheses. From a sample of $n = 300$, the results of regression analyses suggested that the cognitive spaces significantly predicted engagement in creative activities and actual creative achievement in seven of the eight domains assessed. Openness to experience was a significant predictor in half of the domains, whereas the originality of answers in divergent thinking tasks did not significantly predict any domains. The associative task also failed to be a significant predictor. However, the quantity of answers (i.e., fluency) in divergent thinking tasks positively predicted all eight domains, despite reaching statistical significance only towards creative activities and achievements in cooking and music, as well as creative activities in arts and crafts. We discuss the role of the cognitive spaces as well as fluency abilities in predicting creative activities and creative achievements in various domains over and above openness to experience.

Key words: Cognitive Space Theory; Divergent Thinking; Creative Activities; Creative Achievements

Chapter 3

Tittle: Cognitive Spaces and Fluency Abilities Predict Domain-Specific Creative Achievements

Creativity is the beating heart of human progress and innovation. Exploring possibilities is what has propelled us towards exciting and uncharted territories. Without human exploration, we would be stuck in a world devoid of surprise and originality. Each day, our minds navigate a plethora of images, emotions, symbols, and stories. These experiences, according to the *Cognitive Space Theory* (CST; Chapter 1), correspond to distinct fundamental cognitive spaces. Just as a blank canvas provides the space for artists to achieve their painting, fundamental cognitive spaces enable our thoughts and experiences. Our work, hobbies, social life, and everything we do manifest the potentialities that exist within our minds (Glăveanu, 2023).

In this study, we sought to predict the creative activities and creative achievements of a sample of university students from their exploration of fundamental cognitive spaces, their openness to experience, as well as divergent and associative thinking abilities.

The Cognitive Space Theory

The CST (Chapter 1) proposes a "map" which organizes the content of the mind according to ten cognitive spaces. The ten spaces are *image*, *sound*, *movement*, *emotion*, *sensation*, *system*, *symbol*, *strategy*, *network*, and *story*. These cognitive spaces capture the content of domains and activities. For example, the domain of music is thought to mainly exploit the *sound* space, whereas the domain of sports is thought to exploit the *movement* space. The domain of science would exploit the *system* space, and so on. This being said, most domains exploit more than one cognitive space at the time. For example, musical compositions are often structured as stories, and therefore they exploit the *story* space. Indeed, elements of a good story,

such as an introduction, transitions, builds up, and a resolution, are present in most musical compositions. Hence, the combination of cognitive spaces enables the possibilities in our minds. Acknowledging that domains are made of more fundamental cognitive spaces allows to make predictions regarding individuals creative potential in specific domains based on an interest in certain cognitive spaces.

Understanding how our mind navigates a space of possibilities has been the focus of many cognitive theories (e.g., Boden, 2004; Veale & Cardoso, 2019). For example, one influential theory is the theory of Multiple Intelligences (1993) proposed by Gardner. This theory defines seven "intelligences". These intelligences (e.g., musical, linguistic, logico-mathematic) can help understand why individuals have abilities in varied activities. However, contrary to Gardner's theory, the CST was specifically designed to make abstraction of the domains of activities, and therefore it can be used to understand their content (e.g., according to the CST, music explores the *sound* space rather than belonging to a "musical" intelligence).

The exploration of a cognitive space seems to involve three main aspects. First, the space itself (see Boden, 2004) — its content (such as sounds vs. images), its dimensions (depth), and its rules of combination. Second, at the psychological level, the act of exploration involves cognitive mechanisms. Those mechanisms have been studied in depth by researchers in the field of creativity and include divergent thinking, associative thinking, as well as mental simulation among others. Lastly, exploring a space requires a medium. This can be one's own mind, one's own body, a tool such as a camera or a pen, or more broadly speaking a domain of activity such as "science" or "painting". Those mediums interact with a person' motivations, talents, intelligences, goals, resources, self-concepts, and many additional personal and social factors (Csikszentmihalyi, 1998; Kaufman & Baer, 2004; Kaufman & Glăveanu, 2019). For example,

some people prefer to use computer software to create an image, others may prefer acrylic painting. The two certainly "feels" different, although the same underlying space might be explored. Therefore, being interested in a particular cognitive space, such as the *image* space, in combination with elevated cognitive abilities to explore that space, should predict creative activities and creative achievements in a corresponding domain, such as visual arts. An interest for a different cognitive space, such as the *system* space, may predict a creative potential in a different domain, such as in science and engineering.

In this study, we relied on a self-reported tool — the Creative Exploration Questionnaire (CEQ; Chapter 2) — to assess an interest in ten fundamental cognitive spaces, as well as the Inventory of Creative Activities and Achievement (ICAA; Diedrich et al., 2018) to investigate creative activities and creative achievements in eight domains. The domains assessed by this inventory are literature, sports, cooking, science, visual arts, music, arts and crafts, and performing art. The cognitive spaces have only been operationalized recently, therefore their contributions to creative activities and creative achievements have not been researched. Openness to experience is a robust predictor of divergent thinking abilities and creativity across various domains (Feist, 1998; Kaufman et al., 2016; McCrae, 1987; Wolfradt & Pretz, 2001). This trait describes individuals who are open-minded, intellectual, unconventional, adventurous, reflective, introspective, and artistic (Abuhamdeh & Csikszentmihalyi, 2012; DeYoung, 2015b). One goal of this study was to examine the role of the cognitive spaces over and above openness to experience in predicting creative activities and creative achievements in various domains.

The Cognitive Mechanisms Behind Exploration

Exploring a space can be fun in itself. It can also lead to significant insights and learning opportunities. The cognitive mechanisms allowing the exploration of a space can be framed

according to the dual process view of creative cognition. This view posits that the exploration of a space would involve both, associative-automatic "Type 1" processes, in combination with working memory-dependent "Type 2" processes (Allen & Thomas, 2011; Benedek et al., 2023; Benedek & Jauk, 2018; Evans & Stanovich, 2013; Kahneman, 2011; Sowden et al., 2015). This view reconciles two major theories of creative cognition, namely the associative theory and the controlled-attention theory.

The associative theory (e.g., Mednick, 1962) — in combination with the spreading activation theory (Collins & Loftus, 1975) — emphasizes a spontaneous and high capacity spread of activation that occurs within neural networks. Accordingly, the activation of a concept triggers the activation of related concepts in the network, which then spread to other related concepts, creating a cascade of activation. This process is thought to occur automatically and effortlessly. The structure of one's network, such as the strength of the connections between the concepts and the type of connections, influences the spread of activations and thus the associative process. This theory explains how associative thinking occurs, and sheds light onto various creative phenomena, such as incubation, Aha! moments, dreams, and the crucial role of memory and expertise in creative thinking (Beaty et al., 2014; Benedek, Könen, et al., 2012; Benedek et al., 2023; Benedek & Jauk, 2018; Luchini et al., 2023). Evidence for this theory has come from recent cognitive network studies (e.g., Benedek et al., 2017; Kenett, 2018; Kenett et al., 2018; Luchini et al., 2023) which have observed that creative cognition was facilitated by 'flexible' semantic-memory network structures, where concepts were closer to each other and richly interconnected (that is, when a network has "lower average shortest path length, lower modularity, and higher clustering" Benedek et al., 2023, p. 2). In other studies, semantic-memory network structures also predicted greater openness to experience (Christensen et al., 2018), real-

life creative behaviour (Benedek et al., 2017), switching behaviour during memory search (Ovando-Tellez et al., 2022), and interactions between the default, control, and salience networks in the brain (Ovando-Tellez et al., 2022).

The controlled-attention theory is complementary to the associative theory described above. The former highlights the role of executive processes in strategically guiding the search (Beaty et al., 2014; Benedek & Jauk, 2018). Assuming that the solution' space is large and noisy, not all possibilities are equivalently valuable to a specific question or problem. A strategic search is used to constraint the possibilities, give direction, evaluate the options, and optimize the cost-benefit ratio of the search. Evidence for the role of executive processes comes from verbal protocols which identified goal-directed strategies used by creative participants during idea generation tasks (Fleck & Weisberg, 2004; Gilhooly et al., 2007). Additionally, evidence for the role of working memory (De Dreu et al., 2012; Lee & Therriault, 2013), attention-control (Carson et al., 2003; Zabelina, 2018), and fluid intelligence (Beaty et al., 2014; Beaty & Silvia, 2012; Benedek, Franz, et al., 2012; Jauk et al., 2014) during creative thinking are accumulating in the field. Executive processes contribute to the inhibition of interferences (such as stereotyped answers, salient frame of references, or irrelevant stimuli). Additionally, they are responsible for switching to more productive locations within a space, and evaluating potential solutions (Nusbaum & Silvia, 2011; Sowden et al., 2015). Interestingly, non-creative associative tasks such as *list as many animals as possible* also call for controlled attention because "it involves the generation and maintenance of retrieval cues (Unsworth, 2009) and online monitoring of intrusions and repetitions during memory retrieval." (Beaty et al., 2014, p. 3). Hence, even tasks designed to be associative would involve executive processes.

Divergent and Associative Thinking Abilities

Among the tasks most often used to measure creative thinking, Divergent Thinking (DT) dominates the field since 1950 (Guilford, 1950). Broadly speaking, DT refers to a mode of thinking involved in the generation of alternatives (Guilford, 1967). This mode of thinking relies on both associative and executive mechanisms. The generation of alternatives is particularly important during the idea generation phase of the creative process. Typically, DT tasks require participants to generate original ideas to open-ended prompt such as *name all the round things you can think of* (Wallach & Kogan, 1965).

Importantly, although many DT tasks exist, they suffer from poor alternate-form reliability (in the range of $r = .30 – .40$, e.g., Barbot, 2019; Barbot et al., 2016; Runco et al., 2016). As mentioned in Reiter-Palmon et al. (2019), "DT tasks cannot (and should not) be used interchangeably as if they were a direct proxy of a general DT ability (*p*. 145)." Their poor inter-correlations seem to result from "the domain of the task, the time given for resolution (greater individual differences appear with greater resolution time), prior experience with or salience of stimuli used (Forthmann et al., 2016), or the nature of instructions (Harrington, 1975; Nusbaum et al., 2014)" (*p*. 145). Reiter-Palmon and colleagues (2019) stressed the necessity to rely on a range of DT tasks when assessing this construct, as well as accurately labelling the nature of the DT tasks involved. Interestingly, the taxonomy of the Cognitive Space Theory could be used to reveal the nature of those tasks. Indeed, it is plausible that DT abilities interact with the content of a space being explored. As such, DT abilities specific to each space may exist. An alternative hypothesis is that DT abilities are fairly general and allow to search through any space irrespective of their content. In both cases, DT tasks adapted to each cognitive space should be designed to test these hypotheses.

In this study, we investigated the intercorrelations among five DT tasks. The tasks were two alternatives uses tasks (e.g., *tell us all the different ways you could use a Brick)*, two "real-world" problems (e.g., *Martha whishes to visit space, tell us all the strategies Martha could use to visit space)*, and a task that required naming ingredients that have a bitter flavor (see the procedure for more details on the DT tasks). We expected the five tasks to fall within three different cognitive spaces, namely the *system*, *strategy*, and *sensation* spaces, respectively. To code the answers, we focused on a *fluency* of thinking (i.e., the quantity of answers), as well as the *originality* of answers (i.e., their creative quality). The originality of answers was evaluated independently by two judges, following common guidelines (see the procedure section for more details on the scoring scheme). Lastly, we included a measure of associative thinking ability, where participants had one minute to generate a chain of words — in order to separate this ability from a fluency in DT tasks.

This Study

The main goal of this study was to establish the unique contribution of the cognitive spaces, the trait openness to experience, DT abilities, and associative abilities towards creative activities and creative achievements in eight domains. We expected the cognitive spaces, openness to experience, and the originality of answers in DT tasks to have unique contributions towards the creative domains. Divergent thinking abilities and the trait openness to experience have already been shown to positively predict creative activities and creative achievements (Diedrich et al., 2018; Said Metwaly et al., 2022). However, the cognitive spaces were not included in those studies. Moreover, their unique contribution has not been established from multiple regression analyses, where predictors compete against each other (Diedrich et al., 2018). Therefore, the current study attempted to close this gap in the literature.

Additionally, we inspected domain-specific effects of DT abilities using five different DT tasks which we assumed fall in three different cognitive spaces (i.e., system, strategy, and sensation). The two Alternative Uses Tasks were expected to fall within the system space due to a thinking in terms of interchanging *parts* and *functions* — which are components of that space. The real-world problems were expected to fall within the strategy space due to the generation of tactics and strategies. Lastly, the Bitter task (i.e., "name bitter ingredient") was expected to fall within the sensation space, because the latter covers a sensibility to flavors.

Methods

Participants

The final sample was $n = 300$ undergraduate students from a bilingual public Canadian university in the province of Ontario. From the initial 456 recruited, we removed 38 participants who completed the study twice, which we identified through their anonymous participation code. 108 participants got removed due to their low completion rate (60% or less of the questions completed). Two participants got removed after failing the attention check question (*To make sure you are paying attention, please select the second answer*). Univariate outlier inspection revealed six extreme cases which we removed ($Z > 3.5$). Lastly, multivariate outlier inspection based on Mahalanobis distance removed two outliers ($p < .001$, $df = 12$). The final sample was $n = 300$. All participants received one point toward their introductory psychology course for their participation.

Mean age was 18.8 years old (SD = 2.6, ranging from 17 to 48 years old). A majority of participants reported being a woman (79%) and English native speakers (56.2%). Some participants were French native speakers (24.7%) or other languages (19.1%). Participants identified themselves as White (47.7%), Asian (17.7%), Black (16.3%), Arabic (9.3%), Hispanic

(1.3%), or another culture (7.7%). Their programs of study were social sciences (29.7%), health sciences (30.3%), natural sciences (6.0%), management (12.7%), arts (4.3%), computer science (1.3%), or others (15.7%). We asked people to select among a list of 31 domains the one they identify with the most. The most frequent choices are reported in Table 1. The three most popular domains were music (16.6), sports (16.7%) and research (10%) Lastly, participants reported their family socio-economic status as being lower class (0.3%), lower-middle (10.8%), middle (41.7%), upper-middle (44.1%), or upper-class (3.1%).

Table 1. Domains Participants Identified with the Most.

Domain I identify with the most…	Frequency % of selection
Music	16.7%
Sports	16.7%
Research	10.0%
Visual arts	7.7%
Writing/Literature	7.3%
Cooking	5.0%
Other (< 5%)	36,6%

Procedure

The study was conducted online. Participants answered socio-demographic questions and completed questionnaires assessing their interest for exploring and mastering ten cognitive spaces, their openness to experience, their engagement in creative activities and their creative achievement in eight domains, as well as various tasks of divergent thinking. Additional questionnaires unrelated to this study were completed by the participants. The total completion time was on average 45 min. The internal consistency and descriptives statistics for the main variables are reported in Table 2.

Measurements

Creative Exploration Questionnaire (CEQ). Tendencies to explore and master ten cognitive spaces were assessed with the most recent version of the Creative Exploration Questionnaire (CEQ; Chapter 2). This version includes 75 items distributed across ten cognitive spaces and separated in two factors, namely exploration and mastery. We chose to merge the two factors into a single score per space due to very high intercorrelations between the two ($r > .90$). The eight spaces that were used in the subsequent analyses were *system*, *strategy*, *sensation*, *story*, *movement*, *image*, *emotion*, and *sound*. These spaces were the most relevant for the domains assessed in this study. Participants rated their answer on a scale from 1 = (*Very untrue of me*) to 7 (*Very true of me*). An example item for the system space is: "*I learn about specific systems in a supervised context.*" An example item for the strategy space is: "*I like to think of unusual strategies for the fun of it*". An example item for the sensation space is: "*I often invent original ways to use an ingredient*". Lastly, an example item for the emotion space is: "*I engage a lot in emotional exploration*." The factorial structure, as well as its convergent validity towards curiosity, openness to experience, creative self-concept, and its divergent validity towards academic self-concept, were demonstrated in a recent validation study (Chapter 2).

Inventory of Creative Activities and Achievements (ICAA). This inventory aims to assess real-life creativity engagement and accomplishments across eight creative domains (Diedrich et al., 2018). For each domain, six activities and 11 levels of achievements were assessed. Instructions referred to the past 10 years. The domains assessed were literature, sports, cooking, science, visual arts, music, arts-and-crafts, and performing arts. For the analyses, we computed an average of creative activities for each domain, which represents the mean frequency of engaging in various creative activities within a specific domain. Example of activities within

the music domain include: “I made up a melody.” Participants answered on a five-points scale from *never* to *more than ten times*. Next, for the creative achievement variables, we computed the sum for each domain. Higher scores correspond to having reached higher quality of achievements in that domain. The first five levels acknowledge personal accomplishments, from “I have tried this domain once” to “I have already taken classes to improve my skills.” The higher levels cover publicly acknowledged achievements, from “I have already published my original work in this domain” to “I have already sold my work in this domain” (Diedrich et al., 2018).

Openness to Experience. Openness to experience was assessed with the Big Five Aspect scale (20 items; DeYoung et al., 2007). Individuals high on openness to experience tend to display an intellectual curiosity, an enjoyment of aesthetics, a sensitivity to arts, a great imagination, and non-conforming tendencies. An example item is “I see beauty in things that others might not notice.” Participants answered on a 5-points scale ranging from 1 (very inaccurate) to 5 (very accurate).

Divergent Thinking Tasks.

For each divergent thinking tasks, we obtained a fluency score by summing the number of answers. We also obtained an originality score from the evaluations of two independent judges using the top 2 scoring method of Silvia and colleagues (2008). Specifically, the best two answers given by each participant according to the judges were averaged into a single score of originality. Answers that were uncommon, remote, and/or clever were given higher scores, on a scale from 1 (*not creative at all*) to 4 (*highly creative*). The tasks are described hereafter.

Alternative Uses Tasks (AUT). Participants were instructed to come up with as many creative answers as they could to the following two alternative uses items: 1) *Tell us all the*

different ways you could use a brick, and 2) *Tell us all the different ways you could use a newspaper* (Wallach & Kogan, 1965). Participants were allotted three minutes per item.

Strategy Tasks. Participants were instructed to come up with as many creative answers as they could to the following two items: 1) *Your friend Pat sits next to you in class. Pat really likes to talk to you and often bothers you while you are doing your work. Sometimes he distracts you and you miss an important part of the lecture, and many times you don't finish your work because he is bothering you. List as many tactics you could use to solve this problem*. 2) *Martha's birthday was yesterday, she just turned six years old. At her birthday, she made the wish to visit space. Tell us all the strategies Martha could use to visit space*. Participants were given two minutes per question. The first question was developed by Okuda and colleagues (1991; see also Chand & Runco, 1993) as a "real world problem solving" task developed for students. The second question was written for the purpose of this study.

Bitter Task. Participants had to come up with as many creative answers as they could to the following single item: 1) *Name all the ingredients that have a bitter flavor*. This item was exploratory and designed for the purpose of this study to investigate potential domain-specific effects on DT abilities. Examples of some of the answers we received are *green tea, beer, olives, bitter melon, artichokes, arugula, medicine,* and *underripe bananas.*

Associative Thinking. Participants were required to generate as many associated words as possible starting from a given word. The only rule was that each new answer had to be associated with at least the previous one (e.g., book: "paper, sand, castle, …; adapted from Benedek et al., 2012). Participants completed two trials of one minute each. The starting words were 1) Mountain and 2) Book.

Plan of Analyses

First, we inspected the patterns of covariations among the DT tasks and the associative task. Next, we compared four latent models as a way to parsimoniously account for the covariations between the DT tasks and the associative task. Then, we conducted regression analyses with those latent constructs, the cognitive spaces, and openness to experience to predict creative activities and creative achievements in each domain. More specifically, eight multivariate multiple regression models were examined, one for each domain of the ICAA (the creative activities and creative achievements variables were entered simultaneously as dependent variables).

Results

The descriptive statistics and reliability indices for the main variables are reported in Table 2. The lowest reliability coefficient was $\alpha = .68$, which corresponded to creative activities in the literature domain from the ICAA. All the ICAA achievement variables were skewed. This is expected as only few people reach high levels of achievements, hence causing a floor effect. The regression models were estimated with Maximum Likelihood Robust (MLR), an estimator robust to asymmetry.

Intercorrelations Between Divergent Thinking and Associative Thinking

The correlation matrix for the DT scores is reported in Table 3. Starting with the DT originality scores, we can see that the Brick and Newspaper originality scores were highly correlated ($r = .56$, $p < .001$). In contrast, the two strategy tasks were moderately correlated with one another ($r = .41$, $p < .001$). Next, the Brick and Newspaper originality scores were moderately correlated with the two strategy tasks (ranging from $r = .30$ to $.35$, $p < .001$). Lastly, the Bitter task had low but significant relationship with the Brick and the second Strategy task

(Martha going to space; $r = .14$ and .20 respectively, $p < .05$), but not towards the Newspaper and the remaining Strategy task ($r = .07$ for both, $p > .05$).

Now turning our attention to the DT fluency scores (i.e., quantity of answers). We observed strong correlations in-between all tasks except for the Bitter task. The latter had moderate correlations with the others (r ranged from .28 to .39, $p < .01$). Excluding this variable increased the range of correlations ($r = .53$ to .71). Lastly, the two associative items were more strongly associated with one another ($r = .63$), than with the other DT fluency scores ($r = .16$ to .46, $p < .01$).

Exploratory analyses to inspect the validity of the Bitter task suggested that we should remove it. Indeed, the originality score of that task was not significantly related to creative activities in cooking ($r = .11$, $p = .07$), neither with creative achievement in cooking ($r = .09$, $p = .13$), the sensation space of the CEQ ($r = .09$, $p = .11$), or openness to experience ($r = .03$, $p = .65$). Regarding the fluency score, only one correlation among the variables above reached statistical significance, i.e., with creative activities in cooking ($r = .17$, $p = .004$). Therefore, we decided to drop the Bitter task from further analyses considering its 1) low intercorrelations with the other DT tasks regarding the originality score, 2) and the absence of significant relationship between the originality score and activities in cooking, achievement in cooking, the sensation space of the CEQ, and the trait openness to experience.

Table 2. Descriptive Statistics and Internal Reliability Indices for the Main Variables.

Main variables	Min	Max	Mean	SD	Skew	α
Openness to experience	2.45	4.8	3.55	0.45	0.27	.79
CEQ_Image	1	7	3.53	1.21	0.06	.88
CEQ_Sound	1	7	3.33	1.35	0.10	.90
CEQ_Movement	1	7	3.77	1.28	-0.13	.85
CEQ_Sensation	1	6.7	3.69	1.22	-0.09	.88
CEQ_Strategy	1	7	4.10	1.13	-0.42	.79
CEQ_Emotion	1.97	6.9	4.47	1.00	-0.17	.77
CEQ_System	1	6.75	3.89	1.13	-0.20	.86
CEQ_Story	1	7	3.74	1.34	0.02	.85
ICAA Activities Visual	1	5	2.48	0.99	0.33	.82
ICAA Achievement Visual	1	9	2.82	1.90	0.91	n/a
ICAA Activities Sport	1	5	1.99	1.02	0.91	.85
ICAA Achievement Sport	1	10	2.49	1.97	1.27	n/a
ICAA Activities Literature	1	5	2.53	0.79	0.36	.68
ICAA Achievement Literature	1	8	2.50	1.67	0.82	n/a
ICAA Activities Science	1	4.5	1.79	0.82	1.16	.81
ICAA Achievement Science	1	7	2.10	1.51	1.24	n/a
ICAA Activities Performing	1	4.67	1.83	0.72	0.85	.71
ICAA Achievement Performing	1	10	2.51	1.96	1.27	n/a
ICAA Activities Cooking	1	5	2.81	1.03	0.208	.84
ICAA Achievement Cooking	1	7	2.29	1.36	1.00	n/a
ICAA Activities Crafts	1	5	2.89	1.02	-0.01	.84
ICAA Achievement Crafts	1	8	2.61	1.69	0.92	n/a
ICAA Activities Music	1	5	2.05	0.98	0.82	.86
ICAA Achievement Music	1	10	1.95	1.52	1.86	n/a

Table 3. Correlation Matrix for the Divergent and Associative Thinking Scores.

Variable	1	2	3	4	5	6	7	8	9	10	11
1. DT Brick Originality	---										
2. DT Newspaper Originality	.56**	---									
3. DT Strategy 1 Originality	.30**	.34**	---								
4. DT Strategy 2 Originality	.32**	.35**	.41**	---							
5. DT Bitter Originality	.14*	.07	.20**	.07	---						
6. DT Brick Fluency	.44**	.33**	.29**	.28**	.17*	---					
7. DT Newspaper Fluency	.36**	.42**	.27**	.29**	.24**	.71**	---				
8. DT Strategy 1 Fluency	.28**	.26**	.48**	.28**	.26**	.56**	.59**	---			
9. DT Strategy 2 Fluency	.31**	.30**	.23**	.38**	.17**	.53**	.59**	.62**	---		
10. DT Bitter Fluency	.16**	.08	.27**	.12*	.67**	.33**	.39**	.37**	.28**	---	
11. Asso1	.23**	.27**	.16*	.13*	.07	.36**	.40**	.27**	.27**	.16**	---
12. Asso2	.34**	.17**	.17**	.12*	.11	.46**	.44**	.37**	.37**	.19**	.63**

$n = 300$. *$p < .05$. **$p < .01$

Latent Model: Divergent Thinking and Associative Thinking

We compared four latent measurement models (McDonald, 2010) to capture the shared variances in the originality, fluency, and associative scores with latent constructs. The models were Confirmatory Factor Analyses (CFA) with cross-loadings and residual correlations fixed to zero. The intercorrelations between the latent constructs were freely estimated. Model 1 specified two latent factors, namely DT fluency and the associative task grouped, and a second factor with the originality scores from the various tasks together. Model 2 specified three latent factors, by separating the associative items from the fluency items in the previous model. Model 3 specified four latent factors, by further adding a separation between the originality items from the previous model based on the type of tasks (i.e., AUT vs. Strategy). Lastly, Model 4 specified five latent factors, by further adding a separation between the DT fluency items from the previous model based on the type of tasks (i.e., AUT vs. Strategy).

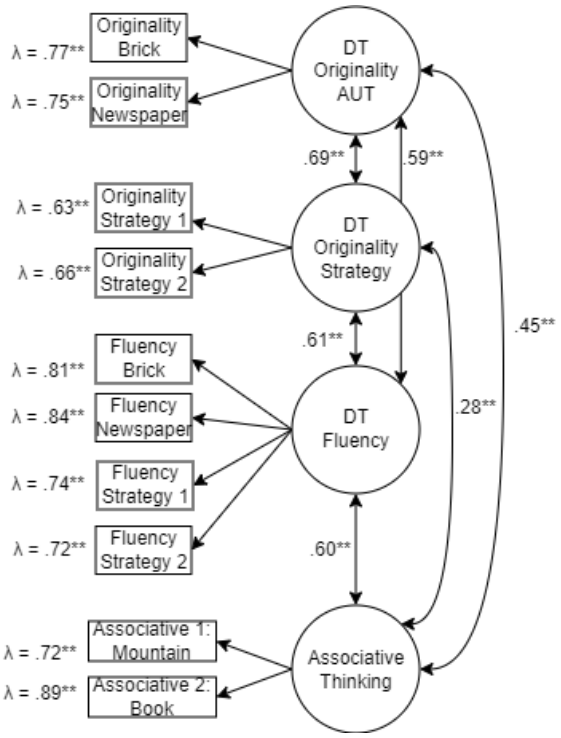
The *goodness-of-fit* indices are reported in Table 3 and the selected model, Model 3, is shown in Figure 1. The poorer fit of Model 1 comparatively to the others indicated that fluency and the associative items were better thought of as separate constructs. Model 2 had a significantly poorer absolute fit than Model 3 (Sattora-Bentler Scaled Chi-Square Difference = 29.48, $p < .0001$). The better fit of Model 3 suggested that the originality scores should be kept separated based on the type of task (i.e., AUT vs. Strategy). Model 4 could not be estimated due to a non-positive definite matrix. The overall fit of Model 3 was good according to conventional criteria (i.e., χ^2 closer to zero, BIC closer to zero, RMSEA < .10, CFI > .90, TLI > .90, SRMR < .05, primary loadings > .40). Hence, we retained Model 3 with four latent variables in the following regression analyses. This model is shown in Figure 1.

Table 5. Fit Indices for the Latent Models of Divergent and Associative Thinking

	χ^2	*df*	BIC	RMSEA	CFI	TLI	SRMR	Loadings λ
Model 1	194.55*	34	10 851.74	.13 [.11, .14]	.82	.76	.07	.49 - .84
Model 2	120.06*	32	10 772.66	.10 [.08, .11]	.90	.86	.05	.52 - .88
Model 3	**94.61***	**29**	**10 628.37**	**.09 [.07, .11]**	**.92**	**.88**	**.04**	**.63 - .89**
Model 4	No fit due to non-positive definite matrix							

Note. *$p < .001$.

Figure 1. Model 3: Latent Model with AUT Originality, Strategy Originality, DT Fluency, and Associative Thinking as Latent Constructs



Note. **$p < .01$. $n = 300$

Regression Results

The results of eight multiple multivariate regressions are reported hereafter. Each included six predictors and two dependent variables. The results are reported through Table 6 panel A to C.

The results are fairly consistent across the eight domains investigated. We can summarize them with three main points. First, the cognitive spaces were robust and consistent predictors of

creative activities and creative achievements across seven of the eight domains. The missing one was performing arts. However, none of the variables were significant predictors towards that latter domain. Second, openness to experience was a positive and significant predictor in only half of the domains, including the literature, visual arts, arts and crafts, and music domains. Third, DT fluency showed a clear pattern of positive correlations with all eight domains. The former was significantly associated with creative activities and achievements in cooking and music, as well as creative activities in arts and crafts. The average standardized regression coefficient for DT fluency was .20 across all eight domains. In comparison, DT originality was not significantly related to any of the domains. The average regression coefficient for latent AUT originality was -.01, whereas the average coefficient for the latent strategy originality construct was -.03 (averaged across the eight domains). Similarly, the latent associative thinking construct was not statistically associated with any of the domains. Its average coefficient was .03.

Overall, 20% of the variance in creative activities were predicted in average by the model. Comparatively, 9% of the variance in creative achievements were predicted in average by the model. The two most consistent predictors across the eight domains were the selected cognitive space and DT fluency abilities.

Table 6. Standardized Results of Eight Multivariate Multiple Regression Models.

Panel A. Results for the Domains of Literature, Sports, and Cooking.

Variables	Activities in Literature	Achivements in Literature	Activities in Sports	Achievements in Sports	Activities in Cooking	Achievements in Cooking
Latent AUT Origin	.01	.20	-.13	-.10	-.21	-.14
Latent Strategy Origin	-.03	-.25	-.16	-.03	-.03	-.02
Latent Fluency	.10	.20	.20	.20	.43**	.33**
Latent Asso	.08	.04	.11	.15	-.14	-.11
Openness to experience	.23**	.17**	.01	.01	.03	.01
CEQ Story	.23**	.17**				
CEQ_Movement			.37**	.21**		
CEQ_Sensation					.45**	.26**
R^2	16.2%**	15.9%**	17.8%**	10.5%**	29.4%**	11.6%**

Panel B. Results for the Domains of Science, Visual arts, and Music.

Variables	Activities in Science	Achivements in Science	Activities in Visual	Achievements in Visual	Activities in Music	Achievements in Music
Latent AUT Origin	-.09	.15	.01	.03	.04	.08
Latent Strategy Origin	.01	-.13	.02	.09	.01	-.10
Latent Fluency	.10	.22	.16	.11	.23*	.26*
Latent Asso	.07	-.05	-.01	.06	.01	-.06
Openness to experience	-.02	.09	.16**	.12*	.13*	.10
CEQ System	.29**	.14*				
CEQ Image			.28**	.18**		
CEQ_Sound					.44**	.25**
R^2	9.2%*	9.1%*	16.3%**	13.0%**	30%**	13.7%**

Panel C. Results for the Domains of Arts and Crafts and Performing arts.

Variables	Activities in Arts&Crafts	Achivements in Arts&Crafts	Activities in Performing	Achievements in Performing
Latent AUT Origin	-.01	-.10	-.11	.14
Latent Strategy Origin	-.05	.08	.05	-.05
Latent Fluency	.28*	.22	.16	.10
Latent Asso	.03	.06	.06	.14
Openness to experience	.15*	.12*	.02	.07
CEQ Image	.28**	.21**		
CEQ_Story			.08	.10
R^2	19.5%**	13.7%**	4.1%	10.8%**

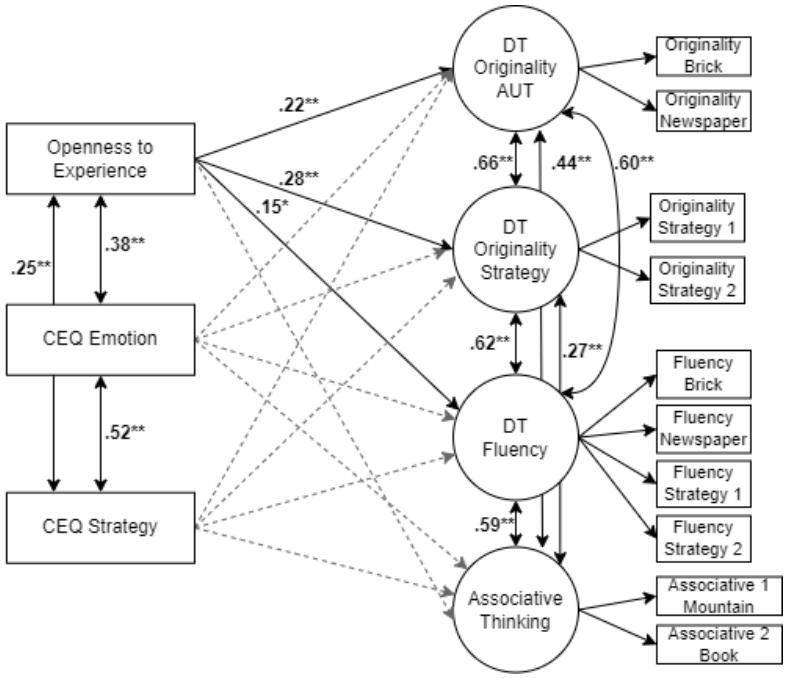
Note. $n = 300$; *$p < .05$; **$p < .01$

Exploratory Analyses: The Cognitive Spaces Predicting Divergent Thinking

We inspected three cognitive spaces in relation to divergent and associative thinking abilities. We selected the cognitive spaces of system, strategy, and emotion. The system space was expected to predict AUT DT, considering that one must think in terms of interchanging parts and functions while finding alternative uses for an object. The strategy space was expected to predict the strategy DT items. Lastly, the emotion space was recently found to predict DT abilities, and therefore we included it as an attempt to replicate this result (Chapter 2). We added Openness to experience to the model to assess the unique contribution of the cognitive spaces over and above this trait.

Due to multicollinearity between the strategy and the system spaces (r = .77), we had to remove one of those two predictors. We removed the system space in order to examine the link between the strategy space and the strategy DT items. Nonetheless, the results were equivalent whether the system or the strategy space got removed. The results are shown in Figure 2. The figure displays only the significant coefficients. Briefly, only openness to experience was a significant predictor of the originality and fluency DT latent constructs. None of the predictor were significantly associated with the latent associative thinking construct. Overall, 5.7% of the variance in AUT originality (p = .08), 7.4% in strategy originality (p = .08), 3.0% in DT fluency (p = .14), and 1.7% in associative thinking (p = .31) were explained by the model. We discuss these finding in the discussion section.

Figure 2. A Multiple Multivariate Regression Model with the Cognitive spaces and Openness to Experience Predicting DT Abilities as Latent Constructs.



Note. The dotted lines are non-significant paths at $p > .05$. Only the significant coefficients are shown.

Discussion

This study investigated creative activities and creative achievements in the domains of literature, sports, cooking, science, visual arts, music, arts and crafts, and performing arts. We expected that an interest towards specific fundamental cognitive spaces, elevated divergent thinking abilities, as well as the trait openness to experience would predict creative activities and creative achievement in various domains. This study found that the cognitive spaces predicted creative activities and creative accomplishments in seven of the eight domains, over and above the other predictors. In fact, the two most consistent predictors across the eight domains were the selected cognitive space in combination with DT fluency abilities. Openness to experience was significantly and positively related to half of the domains. These findings support a relationship

between particular domains of activities and their underlying cognitive spaces, as well as the importance of DT fluency abilities in the creative process.

Domains of Creation

Domains of creations encompass various ways we have to explore and master the possibilities of underlying cognitive spaces (see Chapter 1 of this thesis; also see Boden, 2004; Glaveanu et al., 2013; Kaufman & Baer, 2004). Sports or visual arts, for example, possess equipment, tools, rules, ways of thinking, and codes of conduit, which simultaneously constrain and open up the possibilities of more fundamental cognitive spaces (Boden, 2004; Glăveanu, 2022). They enable us to "navigate" those spaces in certain ways. The current study put this "navigation" metaphor to the test. This study demonstrated the potential of this line of research and the contribution of the cognitive spaces to our understanding of a domain-specific process of creation (also see Glaveanu et al., 2013; Kaufman et al., 2017). Specifically, as few as nine items targeting a space was sufficient to reliably predict creative activities and achievements across a range of domains. For example, creativity in the domain of visual arts was predicted by an interest in the *image* space, creativity in the domain of music was predicted by an interest in the *sound* space, scientific creativity was predicted by an interest in the *system* space, and arts and crafts were predicted by an interest in the *image* space. These findings reveal something about each of those domains. For example, scientific creativity is revealed by grasping the system space. Systems are by definition an interconnected set of parts organized to achieve a function (Meadows, 2008). Therefore, thinking in terms of systems involves identifying the parts, understanding their functions, and recognizing their relationships with other parts. This way of thinking about natural and human phenomena is central to creative proposals in science (Barton & Haslett, 2007; Jirout, 2020; Verhoeff et al., 2018).

Openness to experience failed to significantly predict creative activities and achievements in the domains of sports, cooking, science, and performing arts. Previous studies had found that the two sub-facets of openness to experience, namely *intellect* (reflecting cognitive engagement with abstract and semantic information) and *openness* (reflecting cognitive engagement with perception, fantasy, aesthetics, and emotions; DeYoung et al., 2012), were uniquely associated with scientific and artistic creativity, respectively (S. B. Kaufman et al., 2016). A study by Diedrich and colleagues (2018) showed that openness to experience was positively correlated with all eight domains of the ICAA. The definition of openness to experience as pertaining to a cognitive and perceptual exploration (DeYoung, 2015b; Oleynick et al., 2017) is not far from the notion of exploring fundamental cognitive spaces (see Chapter 1 of this thesis). Arguably, an individual open to all experiences should ascribe value to the exploring all the possibilities of the mind, and therefore should see value in exploring all ten spaces of the CST. Hence, the two constructs overlap. One reason why openness to experience predicted only half of the domains of the ICAA may come from the addition of the cognitive spaces as competing predictors. An important advantage of the cognitive spaces is their specificity. Indeed, the cognitive spaces delimit specific mental contents, such as movements, stories, or emotions, whereas openness to experience is broader in scope. The latter encompasses an interest in arts as well as an intellectual curiosity. The broad scope of openness to experience seems to make it a reliable predictor of various creativity measurements, perhaps at the cost of content specificity.

Fluency Abilities and Creative Domains

Across many domains, the capacity to generate many answers to DT prompts had greater predictive power towards creative activities and achievements than the originality of answers. This is curious considering that generating many ideas (fluency) is not directly tied to the

standard definition of creativity — which involves the production of original and valuable ideas, not just as many ideas as possible (Runco & Jaeger, 2012). In contrast, the originality of answers is more closely tied to the standard definition as it involves the creative quality of ideas. Therefore, we expected originality but not fluency to predict creative achievements. Various reasons may explain this finding.

One possible explanation pertains to the evidence that fluency and indicators of intelligence and executive functions are correlated (Batey et al., 2009; Gerwig et al., 2021; Lee & Therriault, 2013). Considering that studies have found that indicators of intelligence and executive functions predicted creative engagements (Benedek, Franz, et al., 2012; Zabelina et al., 2016), controlling for those abilities could account for the role that DT fluency played towards the creative domains in the current study. Despite this limitation of the current study, our findings suggest that fluency abilities may contribute to many creative activities and facilitate creative achievements. It is plausible that fluently searching a space involves mechanisms which are more general than finding original ideas to a problem. The latter may rely more heavily on task-specific mechanisms. After all, the creative quality of ideas, according to the definition, depends on their novelty and meaningfulness (Runco & Jaeger, 2012). The meaningfulness of an idea must be aligned with the problem posed. In comparison, fluently searching a space does not demand to find anything of value, simply searching. Therefore, it may involve similar mechanisms irrespective of the space (Hills, 2009; Martín-Brufau & Berná, 2021). Notice that the associative 'free flow' task did not predict creative activities nor creative achievements, only fluency in DT tasks did. Thus, fluently searching a space *for original ideas*, but not fluently searching a space for associations, predicted creative activities and achievements. However, the time constraints of those two tasks were not the same, hence this prevents a direct comparison.

Baer (1993) was skeptical of interpretating fluency abilities as domain-general mechanisms. He proposed that many task-specific fluency skills may be involved, such as a fluency in "producing many words that begin with the same sound" (*p*. 95) and a different fluency mechanism for "inventing many metaphors for a given concept" (*p*. 95). These specific fluency mechanisms "may share some cognitive operations, or for some other reason tend to co-occur—or they may be entirely discrete, unrelated skills" (*p*. 95). Yet, his interpretation was based on the results of a series of studies investigating the generalizability of originality skills across various DT tasks (including stories, poems, word problems, and collage tasks), not fluency skills. Notably, Baer found that training improved individuals' originality scores across many DT tasks (see also Scott et al., 2004), but originality in one task barely predicted originality in another. He concluded that "no single factor was found to influence the creative performance of trained subjects in different domains" (*p*. 90), despite apparent training effects across many DT tasks. A different reading of Baer's results would suggest that fluency may explain the training effects, whereas originality in one task may not be a reliable predictor of originality in other tasks, due to greater reliance on task-specific components. Interestingly, the equal odds baseline model makes this exact prediction (Forthmann et al., 2021). This model predicts that increasing total fluency (e.g., from training) increases the number of good ideas, yet it does not affect the hit ratio (the number of good ideas per total ideas). Said otherwise, originality abilities would not be improved by training, only the number of ideas would, which is enough to output more original ideas than before (same hit ratio, but more idea leads to greater chance of generating original ones). The role of fluency and hit ratios across various DT tasks deserve further empirical investigation. As Baer highlights, "the more research evidence we can point to, the more frequently those experiments are replicated, and the more diverse the

indicators that all point in the same direction, the greater confidence we can have in our conclusions" (Baer, 1993, *p*. 94).

Domain-Specific Effects of Divergent Thinking

Divergent thinking is typically thought of as a single, all-purpose, creative thinking ability (Baer, 1993). However, this claim is not grounded into evidence. Some tasks tend to mitigate the effect of prior knowledge and experience, and therefore appear to involve more general processes. For example, naming alternative uses for a brick is one such "general" task. Naming bitter ingredients, however, may accentuate disparities based on prior knowledge. Depending on the kind of task (e.g., verbal as opposed to figural), different cognitive abilities may come into play (Baer, 2012).

One goal of this study was to examine possible domain-specific effects of DT by looking at the cognitive spaces in relation to DT abilities. We administered five different DT tasks assumed to fall within three different cognitive spaces (i.e., system, strategy, and sensation). The results suggested that the system, strategy, and sensation cognitive spaces were not significant predictors of DT abilities, whereas openness to experience remained a significant and unique predictor of DT abilities. These findings contradict previous results whereby the emotion space from the CEQ uniquely predicted DT abilities over and above openness to experience (Chapter 2). The current results cast doubts on the reliability of the CEQ to predict DT abilities. More research is needed to replicate those results. The construct of openness to experience overlap to some extent with the idea of exploring fundamental cognitive spaces. Indeed, openness to experience is akin to a general exploration tendency (DeYoung, 2015b). Previous studies have linked openness to experience to DT abilities (Goulet-Pelletier et al., *in revision*; S. B. Kaufman et al., 2016; McCrae, 1987), as well as with flexible memory networks (Christensen et al., 2018),

better implicit learning abilities (Kaufman et al., 2010), better working memory capacity (DeYoung et al., 2009), greater crystalized knowledge (Ashton et al., 2000), reduced latent inhibition (Carson et al., 2003), and greater motivation to learn (Clark & Schroth, 2010; Goulet-Pelletier et al., *in revision*; Komarraju et al., 2009). Therefore, the trait openness to experience seems to facilitate both the associative and executive mechanisms which are conducive of creative thinking and actual creative achievements (Oleynick et al., 2017). In brief, openness to experience seems better suited to capture the "creative personality" and the "creative cognition", whereas the cognitive spaces seem better suited to examine the specific components of various domains. More research is needed to untangle the link between openness to experience, the cognitive spaces, and DT abilities using varied tasks.

Limit

This study is not without limitation. First, we did not control for indicators of intelligence and executive functions, such as fluid intelligence and working memory. These indicators could have accounted for the relationships we observed between DT fluency and the creative domains. The unique contribution of the cognitive spaces is less likely to be affected by indicators of intelligence and executive functions considering that the former is conceptually closer to a motivational construct. However, these issues require further investigation.

Secondly, despite the fact that we relied on three different types of DT tasks, the lack of validity of the Bitter task, and the limited range of our tasks prevented this study from thoroughly evaluating this aspect. A parsimonious latent model suggested that the generation of original ideas in alternative uses tasks formed a different construct than generating original ideas in real-world strategy problems. Latent modelling also suggested to group the DT fluency scores into a single factor, yet to keep the associative task as a distinct construct. Because we did not

exhaust all possible models, and because more diverse tasks are needed to tackle the issue of domain-specific effects among DT abilities, this study did not and was not intended to conclude regarding this question. Within the limit of this study, the results give credence to task-specific effects especially for the originality score of DT tasks, and tend to support a task-general role of DT fluency. More studies are needed, and a systematic approach to this question is required.

Thirdly, creative activities and creative achievements were assessed in eight domains via a self-reported tool. A wider range of domains and objective measurements could contribute to an understanding of which cognitive space is relevant to which domain. Moreover, distinguishing between the two sub-facets of the trait openness to experience, namely intellect and openness, could result in more subtle understanding of their respective role towards creative domains.

Lastly, we investigated the creative activities and creative achievements of a population consisting in university students with a mean age of 20 years old, in majority woman. Their limited creative achievements, as well as limited creative experiences in general, implies that the predictors could have different weights among more experienced populations. The relevance of the cognitive spaces in predicting creative achievements in more experienced populations deserve further investigation.

Conclusion and Contribution

This study relied on a range of DT tasks, which is a recommended practice within the field (e.g., Reiter-Palmon et al., 2019). More studies comparing various DT tasks are needed to evaluate the contribution of the cognitive spaces in identifying the nature of those tasks and in predicting their covariations. The current study revealed that the cognitive spaces predicted creative activities and creative accomplishments in a corresponding domain over and above

openness to experience, DT abilities, and associative abilities. Fluency abilities in DT tasks positively predicted all eight domains assessed. Predicting student's creative activities and achievements can contribute to identifying their creative strength, weaknesses, and interests early on. This information can help develop their talent and nurture their confidence towards an activity. Besides the predictive validity of the CEQ, one important contribution of the current research was the finding that fluency scores could predict creative activities and achievements more reliably than originality scores of divergent thinking. Fluency is easy to score and amenable to training effects. The apparent generality of fluency abilities across diverse DT tasks, to be contrasted to the apparent specificity of originality, was highlighted by latent structural equation models in the current study. This is an important line of future research which has implication for creativity training and an understanding of DT abilities.

To conclude, people's motivations, talents, goals, and resources interact with a domain of activity. Understanding the composition of domains through their underlying cognitive spaces as well as the role of cognitive abilities in navigating those spaces will contribute to a better understanding of the creative thinking process of individuals. By itself, this study is insufficient to unravel the creative process of university students. However, it demonstrates the potential of this line of research and the importance of assessing cognitive spaces to appreciate the content of creative domains.

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Chapter 4

Implementing Creativity in Education

Abstract

In this chapter, I discuss the implications of a recently proposed psychological theory, namely the Cognitive Space Theory, within the educational context. This theory proposes ten fundamental cognitive spaces. The goal of this chapter is to identify how this theory of cognition combines with existing theories of creativity to cultivate and nurture creativity in school. We argue that although most educational systems effectively promote one aspect of creative thinking, namely *mastery*, the *exploration* component of creative thinking is undervalued. This component is crucial to develop a personal and original approach to disciplines and topics. Next, acknowledging that schools favor some disciplines over others, we dispute based on the Cognitive Space Theory, that 1) the entire range of human experiences deserve serious attention and 2) siloed approaches to teaching should be replaced by a more integrative approach. These two drastic changes are thought to support the creative potential of students and their capacity to generalize learnings to new situations. We review scientific findings pertaining to transfer studies for the domains of visual arts, music, and theatre. We conclude with future avenues of research in neuroscience, cognition, and artificial intelligence.

Keywords: Creativity; Education; Cognitive Spaces; Transfer of knowledge

Chapter 4

Title: Implementing Creativity in Education

People's lives are filled with the consumption of creative products, as they listen to music, watch a movie, visit a museum exhibition, discuss the news, take a photography, or travel in cars. The consumption, distribution, and democratization of novel and valuable experiences and tools have been the hallmark of human advancement. In knowledge-based societies, creativity is a crucial driver of growth and prosperity (OECD, 2010; Winner et al., 2013). The ability to innovate and engage in creative pursuits is essential to successful problem solving and adapting to rapidly changing circumstances. As such, education plays a crucial role not only in fostering the skills and attitudes that we value as a community, but as a powerful way to develop and support the next generation of creators.

Cultivating creativity in school should be informed by evidenced-based educational, psychological, and sociological theories of creativity. Nevertheless, those theories may not always align with the economic priorities or even the culture of a society. In this chapter, we discuss the implications of a recent psychological theory that offers insight into human cognition and behavior, namely the Cognitive Space Theory (see Chapter 1). We consider the consequences of this theory in combination with current theories of creativity for an educational system whose goal is to nurture individual's creative potential with minimal economic agenda. We start by briefly recapitulating creativity theories as well as the Cognitive Space Theory. We address their implications for education and elaborate on the transfer of knowledge, skills, and motivation from one discipline to another. We conclude with future avenues of research in neuroscience, cognition, and artificial intelligence.

The Exploration and Mastery of Possibilities

Why should we want to implement creativity in education? Creativity is a fundamental aspect of human cognition and self-expression. Our capacity to learn, exploit information, and make new connections is deeply engrained in how our brain works. So much so that when we speak of creativity, we usually mean "above average" levels of creativity. Creativity is a process aiming at producing original and valuable work. It involves the participation of many individuals, tools, and systems (Clapp, 2016c; Csikszentmihalyi, 1999; Glăveanu, 2014), and individuals' participation in this creative process is part of their human capital (Barbot et al., 2017; Walberg, 1988). Researchers have identified the main components of a creative cognition. Key factors underlying a creative cognition involve a quality of motivation, optimal levels of intelligence, an open personality, a goal-directed thinking style, flexible knowledge acquisition, and opportunities from a nurturing environment (Amabile, 1983; J. C. Kaufman & Baer, 2004b; Sternberg & Lubart, 1991). Hence, to become a *creator* — i.e., someone who proposes new and valuable ideas and who possess the skills needed to exploit these ideas to their fullest —, one must flexibly acquire knowledge and strategically explore a space of possibilities (see Chapter 1 and Chapter 2). This already has implications for educational systems. Most modern educational systems are competitive environments that typically emphasize and reward knowledge acquisition more than anything else (Robinson, 2011). Students compete for grades, which are yielded to the successful demonstration of knowledge and skills. As a result, most educational systems seem to effectively promote one aspect of creative thinking, namely *mastery*. Mastering a technique or gaining a deep understanding of a topic is the basis of high-quality creative products (Baer, 2015; Simonton, 1994). Mastery suggests rigor, practice, and perseverance (Gardner, 2011). It is needed to fully exploit an idea. For example Shakespeare demonstrated a

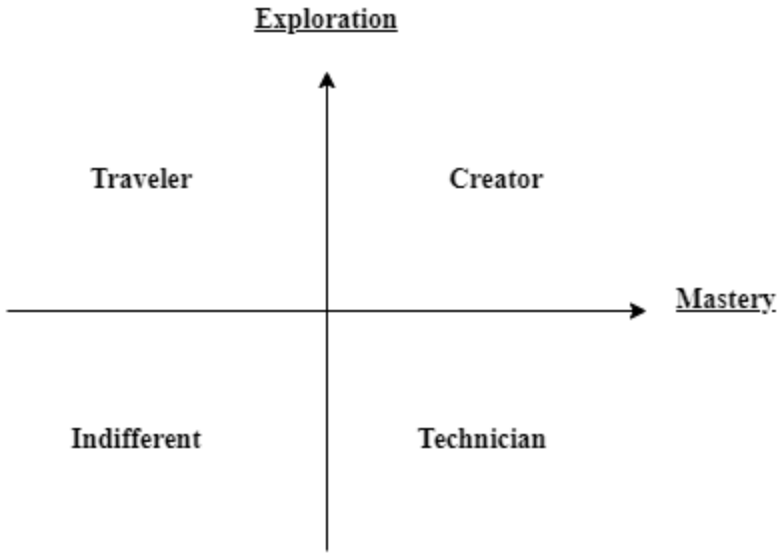
mastery of the complexity of characters, the richness of the English language, and a deep understanding of timeless themes that continue to resonate with audiences today. The greatest creator of all time mastered their art and discipline (Gardner, 2011, examined a few cases e.g., Einstein, Picasso, etc.). But mastery alone is not sufficient. A second necessary component is *exploration*.

Students with a mindset of exploration in school aspire to push the boundaries of knowledge further, experiment with novel approaches, propose their own ideas, and engage in self-directed learning (Barak & Levenberg, 2016; Burleson, 2005; Gube & Lajoie, 2020). Indeed, through questioning, testing hypotheses, making observations, recognizing patterns, and making inferences, students develop a personal approach to problems and a deeper understanding of the possibilities within a field (Baer, 2015; Burleson, 2005; Jirout, 2020; Ronfard et al., 2018). In doing so, they hone their "creative skills", which include divergent thinking (i.e., a capacity to generate variations), associative thinking (i.e., a capacity to generate semantic associates), mental simulation, improvisation, critical thinking, and heuristics such as seeking analogies (Gube & Lajoie, 2020; Jaccard & Jacoby, 2010). Exploration and mastery are compatible goals, because once a new and potentially valuable idea has been found through exploration, mastery is required to exploit it. Moreover, mastery contributes to recognizing the potential value of new ideas (Baer, 2015). Likewise, the constructive process of seeking information and making new connections is a more effective means of learning than simply receiving information (Beghetto & Kaufman, 2007; Chi & Wylie, 2014; Jirout, 2020; Lamnina & Chase, 2019). It is natural for young children to learn through exploration (Piaget, 1959). Unfortunately, exploration is undervalued in most educational systems, especially past a certain age (Robinson, 2011). Students are often shown unambiguous information, they are encouraged to be "right" all the time, and they do not

necessarily identify gaps in their knowledge as opportunities to learn (Jirout, 2020; Martin, 2011; Martin & Marsh, 2003). In addition, learning opportunities tend to focus on the outcome at the expense of the process, with little opportunities to generate one's questions and steps along the way (Chouinard et al., 2007; Jirout, 2020; Jirout & Zimmerman, 2015).

A focus on mastery in school tends to produce *technicians*, i.e., individuals with very good techniques and relevant knowledge but a lack of autonomy in proposing their own ideas (Chapter 2; see also the concept of routine experts in Gube & Lajoie, 2020). This is shown in Figure 1 with the 2 × 2 model of the creator (see Chapter 2). For example, musicians who can play existing compositions to perfection, but who cannot improvise, would fall in the technician category. In contrast, exploration without mastery tends to produce *travelers*, i.e., individuals with poor technical skills despite being autonomous in proposing new ideas. For example, musicians who can improvise, yet have a hard time playing any existing compositions, would fall in that category. Lastly, individuals who do not explore nor master are considered *indifferent* towards an area of creation (see Figure 1). Theories of creativity converge towards the fact that students should understand the value of both 1) mastering relevant techniques and knowledge in a field and 2) autonomously exploring possibilities — to develop their creative potential to its fullest.

Figure 1. *The 2 × 2 model of the creator.*



Note. Exploration is defined as "seeking novelty". Mastery is defined as "the acquisition of knowledge and techniques". This figure was taken from Chapter 2 of this thesis.

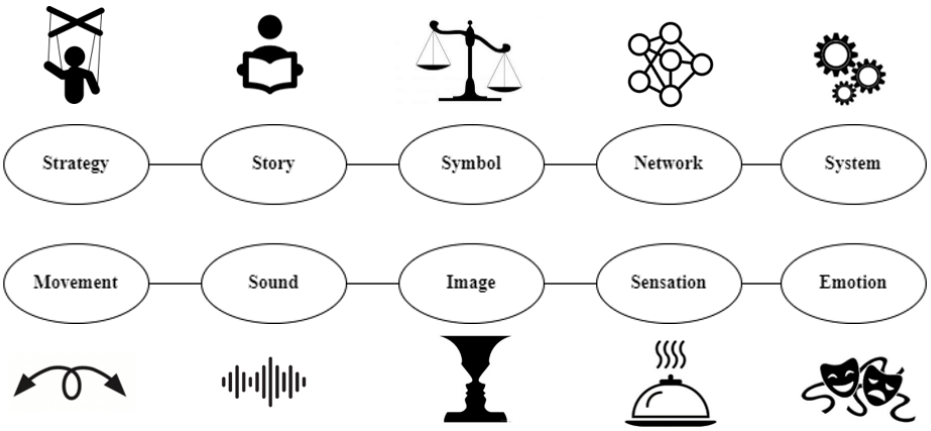
The fallacy of Arts vs. Sciences

> *We are not students of some subject matter, but students of problems. And problems may cut right across the borders of any subject matter or discipline.*
>
> - Karl Popper

The fallacy of art vs. science is to believe that one requires rigorous thinking and not the other, or that one is "serious" and not the other. Arts and sciences are both important as they are an integral part of human experience (Winner et al., 2013). Failing to notice creative productivity in disciplines other than in arts is common. Indeed, creativity is less obvious when the product is not a perceptual experience. The Cognitive Space Theory (CST; elaborated in Chapter 1) is a recent theory designed to unravel *what creativity looks like in all of its forms*. The CST proposes that all activities and disciplines serve as means to interact with more fundamental cognitive spaces. Those cognitive spaces capture fundamental psychological units, such as emotions, movements, symbols, and stories. Those units are thought to be the foundations of our minds.

Different activities can be used to navigate the same space of possibilities. For example, photographers and painters may both think in terms of colors, shapes, perspectives, visual angles, and light. These aspects are the psychological units of the *image* space. In another vein, actors and therapists must think in terms of *emotions*, while engineers and scientists must think in terms of *systems*. Identifying the cognitive spaces that underlie different activities can help highlight their similarities and differences. The CST defines ten cognitive spaces, as shown in Figure 2 (also see Chapter 1). They are *strategy* (e.g., goals, optimization, procedures), *story* (e.g., characters, intro, transitions), *symbol* (e.g., words, numbers, maps), *network* (e.g., social relationships, semantic associations), *system* (e.g., clock, car, biology), *movement* (e.g., forward, backward, jumping), *sound* (e.g., pitch, volume, intensity), *image* (e.g., colors, shapes, light), *sensation* (e.g., sugar taste, mint odor, skin sensations), *emotion* (e.g., pain, anger, pride). As another example, consider social interactions. All social encounters call upon a type of relationship (lover, friend, colleague, etc.) which is part of the *network* space; the vocalization, which is part of the *sound* space; narratives and stories, which are part of the *story* space; and an emotional transaction, which is part of the *emotion* space. The coordination of those spaces is what makes social interactions a complex and experientially rich phenomenon.

Figure 2. An Organization of the Ten Spaces of the Cognitive Space Theory



Note. This figure was taken from Chapter 1 of this thesis.

The CST works as a “map” so to speak. Grasping the depth, content, and dimensions of each space enables to recognize creativity as it manifests in most disciplines. It can also guide the development of school curriculum, help individuals identify their own creative strengths and weaknesses, and ensure that the entire range of human experiences is given proper attention. The theory covers artistic and non-artistic activities. Hereafter we discuss two of the main contributions of the CST in education. First, the ten spaces are hierarchically equal, therefore no discipline is intrinsically better than another according to a cognitive perspective. Second, the cognitive spaces cover the entire range of human experiences.

A Hierarchy of Disciplines in School

Disciplines are not valued equally in school. Education systems around the world tend to prioritize language and communication, as well as Science, Technology, Engineering, and Mathematics (STEM), followed by social sciences such as history, geography, economics, and political science, and finally physical education, computer science, religion, and arts (OECD, 2011). This prioritization unveils itself through the time that students spend on each discipline, the amount of homework, the weight of the evaluations, and the rigor and expectations of the learning outcomes. For example, judging whether a student may skip a grade, or stay an extra year, rarely revolves around their performance in physical education or music (Winner et al., 2013). The hierarchy of disciplines in school has been shaped by economic forces, cultural preferences, and political priorities. The current chapter wishes not to argue against a strategic approach to education. However, the CST points to the valorization of all human experiences and the need to replace siloed approach to learning by a more integrative approach.

The full range of human experiences deserves serious attention. More than ever before, workforces rely on a broad mix of skills because creative products are becoming more and more

complex and are proposing richer experiences (Winner et al., 2013) The main contribution of the CST is its map analogy. It can be used to identify those human experiences which have been depreciated in most OECD educational systems. Among the human experiences least likely to receive explicit attention in school, we find the *emotion, strategy,* and *sensation* spaces.

Emotions are often considered less serious than other disciplines of the mind. Yet, the pressure of competitive environments, the social arena imposed by society and human nature, the external and intrinsic motivational forces at play, the need to self-regulate, and personal issues, are all valid reasons to acknowledge the value of the emotion space. Currently, 450 million people worldwide struggle with mental illness, making it the leading cause of disability according to the World Health Organization (2022). In Canada, it prevents nearly 500,000 employees from attending work each week. Mastery of the emotional space has been framed according to the concept of emotional intelligence (Goleman, 1996). Mastery is the acquisition of knowledge and skills. Therefore, correctly decoding and correctly responding to an emotional proposal is part of what is meant by emotional mastery. Being able to honor one's emotions without repressing or exploding is another aspect of emotional mastery — this means understanding the information conveyed by sadness, joy, or anger. In another vein, empathy is a *creative skill* that can be used to explore the emotions of others (Decety & Grèzes, 2006). Experience with the emotion space can be acquired through social interactions, theatre, acting, therapy, mental simulations, and empathic skills. Actors, therapists, filmmakers, storytellers, and music composers are some of the professional creators of emotions. Indeed, emotions can be crafted and consumed by others. For example, movies, books, and music propose complex moments of joy, melancholy, or fear to be figuratively consumed by an audience. Those media contribute to everyone's understanding of the possibilities of the emotion space. The emotion

space requires serious thinking and as much practice as any other cognitive space considering its depth and complexity.

In any competitive environment, strategies are valuable. The strategy space has been fundamental to human survival and success (Freedman, 2013). Setting goals and planning is sometimes taught explicitly and even rewarded in school. Nevertheless, the focus is too often on achieving good grades. Rarely strategies are valued as creative products in their own right. In addition, rarely the exploration of new strategies is noticed and acknowledged. Focusing on strategy in school could be achieved, for example, by requesting students to do an exam with half the time it should take. The preparation beforehand in terms of study strategies, as well as the choice of strategies during the test could be directly evaluated. Strategizing is valuable in work contexts as well as in personal lives. Dealing with obstacles and goals outside school could be integrated in academic evaluations. At a professional level, creative strategists include business leaders, managers, administrators, politicians, competitive game and sport players, and coaches. Opportunities to hone one's strategic skills can be retrieved in sports, board games, video games, puzzles, social contexts, managing tasks, and in any competitive context. Creative strategizing is valuable for efficient problem solving and flexible adaptation to change. Creative thinking in this space requires that individuals learn about existing strategies and explore new ones.

Lastly, the sensation space covers the experiences of taste, smell, and touch. Cooking chefs are a predominant figure within that space. Many cognitive spaces are involved in cooking. A creative meal must possess great flavors, great odors, great look, it must be well-balanced, complex, deep, and even perhaps surprising. In addition, cooking can become a sport whenever rapid, enduring, and precise movements, as well as strategies, come into play. Lastly, the science behind cooking is both extremely rich and useful (Provost et al., 2016). It can be leveraged to

learn analytical skills applied to complex chemical systems. Notably, many schools have mathematical and spelling competitions, so why not have cooking competitions? Cooking is part of many self-reported questionnaires of creativity (e.g., Carson et al., 2005; Diedrich et al., 2018). There is a fairly good consensus towards its relevance in creativity research. However, cooking is typically excluded from most school curriculum. This is unfortunate considering how rich and useful cooking is and how many cognitive spaces are involved in mastering and exploring this discipline.

Abandoning Siloed Approach to Learning

Siloed approaches to learning assume that the content of each discipline is fairly homogenous and independent. Therefore, these approaches typically separate each discipline into distinct classes (Robinson, 2011). Students must change rooms, change teachers, and change their mindsets and motivational approaches to fit the needs of each class. Also, each discipline is graded in silo. This siloed approach reinforces the belief that learning a specific discipline occurs only during the time explicitly given to that discipline. Although this is the most direct form of learning, it prevents individuals from accessing their entire set of knowledge and skills whenever they are facing a new context or situation (Rounsaville et al., 2008; Winner et al., 2013). This is due to compartmentalized learning. For example, a study on the meta-cognition of students in writing tasks found that despite their wealth of knowledge about different genre and despite having written in a number of different domains, students tended “not to draw on the full range of their discursive resources when confronted with a new writing task in college” (Rounsaville et al., 2008, p. 105). Students tended to frame the task as a “school-task” and reported “only utilizing genres they associated with school despite their wide genre repertoire” (Rounsaville et al., 2008, p. 106).

Transfer of knowledge and skills to new situations may only happen if individuals understand the deep, underlying, commonalities between different activities and contexts. For example, language is a complex vector which exploits the cognitive spaces of *sound*, *symbol*, *system*, and *network*. Indeed, those spaces are exploited by the phonology of words, the words themselves, the rules of grammar, and the semantic meaning, respectively. Therefore, creativity in language can manifest in each of those spaces. For example, new sounds can be proposed, new words can be invented, new sentence structures can be experimented, and new meanings can be generated. Understanding which cognitive spaces are relevant to which disciplines enables individuals to concentrate their learning and exploration efforts in the appropriate areas. Additionally, for the example of language, because it relies on the coordination of many cognitive spaces, a deficit in one of them may translate into a deficit of communication, such as a lack of fluency in the sound space may translate in a failure to grasp the phonetic aspect of words. Therefore, the theory could be used to develop targeted interventions.

Siloed approach to learning should be replaced by a more integrative approach, if the goal is to nurture creative thinking. In a different educational system, one based on the principles of the CST, the typical classes such as music, mathematics, and physical education, would be replaced by their underlying cognitive spaces. For example, a class about *movement* could cover sports, video games, dance, and up to instrument playing; a class on *system* could cover linguistic, mathematics, engineering, design, science, medicine, mechanic, and music theory. Classes on *symbol* could cover the symbolic-to-referent nature of words, numbers, and other symbols used in mathematics, engineering, and music, as well as social symbols, historical symbols, visual symbols such as tattoos, and so much more. Classes on *story* could cover writing, filmmaking, theatre, video editing, social interactions, musical composition, poetry, and

marketing among others. Classes on *sound* could cover music, acting, social interactions, oral presentations, sound design for films and video games, and more. Classes on *network* could cover memory networks, conceptual networks, social networks, animal networks, and the importance of social networks in politics, business, and war.

Certainly, the media and tools we have used to explore the possibilities of our minds have changed over time. For example, the advent of photography caused important shifts in the way images were produced. It made painters fear becoming obsolete and most recently, digitalized art and artificial intelligence are doing the same. Despite that technology has transformed our interactions with the image space — as with all the other spaces — the image space has been there all along. The advantage of teaching for the underlying cognitive spaces is that they offer a stable learning agenda, which focuses on the core elements which unite various activities. This should foster a deeper understanding of the content and structures of disciplines, and thus promote creative insights.

Transfer of Learning: What do We Already Know

The CST highlights the common structure and content of a priori different disciplines. Therefore, it can guide studies on transfer. The goal here is to identify knowledge and skills which may transfer from one context to another, and to teach for transfer in school. Transferring learnings to new situations can speed up the acquisition of new skills and promotes creative thinking by facilitating the resolution of new problems, offering new perspectives on a topic, expending the resources and inspirations of individuals, and affording new opportunities for collaboration and the exchange of ideas (Barnett & Ceci, 2002).

Transfer of knowledge and skills is notoriously difficult to demonstrate and has rarely stood up to expectations (Barnett & Ceci, 2002; Bransford & Schwartz, 1999; Detterman &

Sternberg, 1993; Halpern, 1998; Schwartz et al., 2005; Winner et al., 2013). Winner and colleagues (2013) reviewed key findings from the literature on transfer from arts programs, expanding on the meta-analytic studies of Winner and Hetland (2000). Hereafter, we provide an overview of the type of transfer that has been demonstrated. The most solid evidence has been for the domains of visual arts, drama/theatre, and music, which we review below. Note that these findings were not based on studies that explicitly taught for transfer. This being said, the findings are highly consistent with the CST.

Transfer from Visual Arts

Reading visual information, analyzing, interpreting, and understanding how visual elements such as color, shape, line, and texture convey meaning has been termed "visual literacy". The skills developed by visual literacy are potentially useful in jobs such as radiology, design, criminal investigations, video editing, marketing, surgery, chemistry, and geology (Hetland et al., 2015; Winner et al., 2013). Research has shown that the one skill in visual arts education for which we have convincing evidence for transfer pertains to visual *observation* skills. For example, in one experimental study, Tishman and colleagues (1999) found that 9- and 10-year-old children who were taught to look closely at works of art, and to talk about what they saw, improved their performance and reduced their circular thinking in identifying the correct fossil record for intersecting animal footprints. This is an example of transfer because the skills of looking and reasoning about what is seen are transferred from paintings to images of footprints. Furthermore, another promising area identified by the report was spatial reasoning abilities, which might transfer between visual arts and geometry. Nonetheless, more studies are needed to examine this claim. According to the CST, far transfer in the *image* space could occur

between all visual arts, as well as dishes presentations, fashion, and dance, among others, due to commonalities in thinking in terms of colors, shapes, lighting, and perspectives.

Transfer from Music

Training in music is often claimed to improve mathematical abilities (James, 1995; Krumhansl, 2000; Nisbet, 1991; Shuter-Dyson, 1999; Winner et al., 2013). Indeed, musicality and harmonics follow a system of intervals and ratios. In addition, musical notations follow a specific grammar-like structure and make use of symbols. Evidence that some forms of music instruction are associated with improved mathematical reasoning has been found (Vaughn, 2000; see Winner et al., 2013 for a review). However, more studies are needed to link specific kinds of mathematics abilities with specific content of musical training, and vice versa. For example, teaching music theory as an internally consistent system is more likely to develop knowledge useful to mathematical thinking, compared to teaching the acoustic component of music. On a different note, research has demonstrated that music training improved phonological awareness and word decoding. As reviewed by the report, musicians possess "superior linguistic pitch processing (Marques et al., 2007; Schön et al., 2004), a superior ability to detect prosody from spoken language (Thompson et al., 2003) and a superior ability to identify a speaker's emotion from that speaker's prosody (Nilsonne & Sundberg, 1985; Thompson et al., 2004)" (Winner et al., 2013, p. 93). By the same token, adults trained in music had superior abilities at imagining and comparing environmental (non-musical) sounds (Aleman et al., 2000; Patel, 2010; Peretz & Zatorre, 2005). These findings suggest that training acoustic abilities through music can improve speech recognition abilities. More research is needed to evaluate if far transfer in the *sound* space happens between music, cinema, video games, social interactions, theatre, teaching, and poetry, among others.

Transfer from Drama/Theatre

Training in drama/theatre call upon the memorization of verbal scripts, understanding story-content and story-characters, and enacting those characters. This training puts an emphasis on story comprehension, verbal skills, and emotional skills. The report concluded that there was "clear causal evidence that training in classroom drama improves a wide range of verbal abilities, including reading and story comprehension" (Winner et al., 2013, p. 155). Likewise, children who acted out stories understood the stories better compared to simply reading them (Podlozny, 2000). Regarding emotional skills, the report concluded that there was "mounting evidence that learning in theatre helps children to adopt the perspectives of others, and hence increases psychological understanding of others mental states" (Winner et al., 2013, p. 233). Training in drama also contributed to emotion regulation strategies such as expressing rather than suppressing, as well as empathic skills (Goldstein & Winner, 2010, 2012; Winner et al., 2013, p. 223) The evidence reviewed above suggests that training in drama/theatre can improve verbal abilities, story comprehension, and emotional regulation. Research should investigate far transfer in the *emotion* space between therapy, acting, filmmaking, writing, and personal emotions more generally. In addition, far transfer in the *story* space could be inspected between writing, music composition, marketing, teaching, and political discourses.

Pitfalls of Transfer Studies

The report concluded that one priority was "to develop sound and testable theories about why and how arts education would have an impact on various outcomes of interest" (Winner et al., 2013, p. 256). The CST is one such testable and sound theory of transfer. The CST makes strong claims about the transfer of knowledge, skills, and motivation. Three precautions are warranted, however. First, the cognitive spaces identified by the theory are vast and deep. Thus,

two disciplines can explore the same underlying cognitive space but at very different locations. This implies minimal transfer potential. For example, marathon runners and archers both exploit the *movement* space, but admittedly at very different locations within that space. In contrast, archery and other precision activities like video games have greater transfer potential in this regard (but see the third point hereafter).

Second, if skills and knowledge do transfer, it may only occur when explicitly taught so (Barnett & Ceci, 2002). Meta-cognitive reasoning is required for transfer to occur. Thus, individuals must be taught about the connections which exist between seemingly distinct contexts (Winner et al., 2013). This meta-cognitive reasoning involves answering: What am I doing right now? Why am I doing it? And how does it help me? The CST can help answer those questions and thus, it may contribute to the meta-cognition needed for transfer to happen.

Third, it is recommended to move beyond the traditional approach of transfer whereby learning in one domain is assumed to predict greater achievement in a transfer domain. Instead, learning in one domain should be expected to lead to greater preparation for future learning in a transfer domain (Bransford & Schwartz, 1999). As Winner and colleagues (2013) explained, instead of expecting students with visual art training, for example, to score higher on geometry, one should expect them to be more able to learn geometry (or learn it more quickly) once in a learning situation — compared to those without visual art training.

To conclude this section, the transfer of knowledge is a valuable asset which allows individuals to learn and adapt more efficiently to new situations. It contributes to the proposition of creative ideas based on a greater variety of experience, knowledge, and skills which are adequately applied to solve new problems and answer new questions. Transfer is usually not automatic, and therefore it requires a meta-cognitive understanding of why, what, and when

transfer is possible. This meta-cognitive understanding constitutes a theory in itself. A strong and evidenced-based theory is needed for transfer to occur reliably. The CST was specifically designed to organize the content of activities, domains, and disciplines according to their underlying cognitive spaces and psychological units. In so doing, it is a plausible theory of transfer and a promising avenue for future research.

Avenues for Future Research

The implications of the CST for educational systems depend on its validity. It is imperative to test and evaluate the principles of this theory before implementing its modalities. Testing the CST calls for a research agenda spanning across multiple disciplines, including neuroscience, cognitive science, and computer science.

Neuroscience

Neuroscience methodologies allow us to study how the brain processes information, how different regions of the brain communicate, and how brain activity is linked to specific behaviors. An important question to ask is whether involvement in a particular cognitive space alters the brain *in ways that makes learning new activities tapping on the same cognitive space more possible* (Winner et al., 2013). For example, it is now well-established that processing music and speech involves shared brain areas, such as the Broca area (Hallam et al., 2011; Kunert et al., 2015; Peretz & Zatorre, 2005). Further evidence suggest overlapping but distinct networks for music and speech within the same cortical areas (Abrams et al., 2011; Rogalsky et al., 2011; see Peretz et al., 2015 for a review). Moreover, music training improves speech recognition abilities (see Winner et al., 2013 for a review).

The CST can be tested by neuroscience considering that each space and each unit should possess its own *brain signature*. A brain signature is a model that “includes features that span

multiple brain systems" (Kragel et al., 2018, p. 269). Contrary to traditional brain mapping whereby isolated brain regions are associated with local encoding of information, brain signature models specify the joint activity of neural systems and use this communication as a model to predict behavioral or mental outcomes. Cognitive spaces are expected to have brain signatures instead of localized areas for each of them considering that complex representations, such as a story, require the communication between many localized areas. The signature for a *story-structure*, for example, should be detected whenever one thinks in terms of a story-structure but not otherwise. The signature should respond to tasks such as music composition, video editing, writing, and thinking about narrating one's weekend to a friend. Only then, evidence for a common "story-structure unit" may be found (Kragel et al., 2018). Alternatively, the signature might reflect only a subtype of story-structure, such as generating a structure for an internet meme vs. a journalism text, indicating that the brain includes distinct processes that can be labeled as story-structures (Kragel et al., 2018). Within each cognitive space, units may have different signatures, such as thinking about an intro vs. a conclusion, within the story space. The signature for an intro would have to generalize across contexts and stimuli. As such, an intro for a musical composition and for a text would have the same brain signature. If signatures generalize across disciplines and activities, then the CST might be a valuable guide to researchers. Lastly, if a signature is not unique but responds to other unrelated events, then the former can be falsified and our understanding of what it measures can be refined (Kragel et al., 2018).

As reviewed in Kragel et al. (2018), some studies have already identified reliable brain models for emotion categories such as fear and anger, which generalized across music and film clips (Kragel & LaBar, 2015), short movies and mental imagery (Saarimäki et al., 2016), and

across methods of emotional induction (Wager et al., 2015). Moreover, studies found reliable neural patterns of emotions in the medial prefrontal cortex (MPFC), even in the absence of observable expressions, i.e., when the emotion was inferred from situational information (Skerry & Saxe, 2014). Another study found that emotional patterns generalized across faces, voices, and body cues (Peelen et al., 2010). These findings, although selective, are compatible with the CST, because emotion models could be identified, and these models were independent of the contexts and stimuli. More research is needed to develop models which test and improve the principles behind the CST.

Cognition

Cognitive science is an interdisciplinary field concerned with topics such as perception, intelligence, memory, attention, language, decision-making, and the role of emotions. Research in cognition has already accumulated evidence for each space of the CST. For example, a classic experiment by Heider and Simmel in 1944 showed to participants an animation of moving geometric shapes. The short animation exhibits a big triangle seemingly "bullying" a little triangle and a circle. To the surprise of the experimenters, nearly all participants came up with a fairly detailed "story" of what was happening. Participants attributed intentions and goal-directed behaviors to the "characters" of the animation despite the lack of cues such as body language, facial expressions, or speech. This study was taken to reveal that humans have a strong inclination to interpret and understand the world around them in terms of human-like agency and intentionality. From the perspective of the CST, it revealed the pervasive effect of stories in our mind. In another vein, stories, emotions, and symbols have been studied in-depth from the phenomenon of *pretend play*. Children from the age of 2 years old naturally experiment with the social roles of life by enacting these roles and using objects, actions, or ideas to represent other

objects, actions, or ideas using their imaginations (Thompson & Goldstein, 2019). The CST can contribute to organizing the literature in psychology, which may help accumulate knowledge and reach a greater consensus within the field.

New promising avenues of research include looking at how the cognitive spaces combine to form rich experiences, such as how movies combine the *image*, *sound*, *story*, *emotion*, and *symbol* spaces into one consumable product. Another direction of research is the dynamic interactions between attentional mechanisms, memory, and thinking abilities. Indeed, different attentional channels and specific cognitive mechanisms may be relevant for different spaces. Throughout one's life, granting more attention to certain cognitive spaces should translate into richer networks of experiences and memories for those mental contents. Therefore, brain network methodologies can be used to study the memory structures associated with each space. Network methodologies are based on mathematical graph theory and offer powerful quantitative methods to investigate cognitive structures such as semantic memory (e.g., Beckage & Colunga, 2016) and the mental lexicon (e.g., Aitchison, 2012; see Siew et al., 2019 for a review). The interaction between rich memory networks, cognitive abilities, and attentional mechanisms at different stages of the creative process has already provided important insight into the psychology of creativity and memory (e.g., Benedek et al., 2017; Kenett, 2018; Kenett et al., 2014; Li et al., 2021; Luchini et al., 2023). A future avenue is to unravel "space-specific" creative potential (J. C. Kaufman et al., 2017).

Lastly, developing tasks to assess thinking abilities in each cognitive space could benefit psychology as a whole (Barbot, 2019; Barbot et al., 2017). Indeed, valid and reliable cognitive tasks suited for each space will contribute to assessing the entire range of human experiences, as well as testing and falsifying the theory. Notably, a self-reported questionnaire called the

Creative Exploration Questionnaire already exists (Chapter 2). It assesses all ten spaces of the CST with the factors of mastery and exploration. However, the questionnaire only possesses six to nine items per space, which is limited considering the broad scope of each space. Besides that, the validation study of the questionnaire suggested that the cognitive spaces of *network*, *system*, *symbol*, and *strategy* were considerably correlated. Self-reported questionnaires are based on individuals' subjective perceptions and reflections. Notably, the cognitive spaces which individuals seem to have the most difficulty distinguishing also happen to be those for which creativity is the least obvious to detect and therefore the least recognized socially. Despite these limitations, the questionnaire robustly predicted creative activities and creative achievements over and above the trait openness to experience and divergent thinking abilities in seven domains, including science, sport, and cooking (Chapter 3). More specific questionnaires should be developed for each space and objective measurements will be needed to assess cognitive abilities in navigating each space.

Artificial Intelligence

An important domain of research in cognitive sciences is Artificial Intelligence (AI). The CST is compatible with a computational approach to psychology. In fact, the theory was greatly inspired by the work of Boden (2004) in the field of computational creativity. The CST stipulates that each cognitive space should possess identifiable *units*. These units can be *combined* or *broken down* into smaller components. This suggests that once mental units are identified, cognitive mechanisms of combination and deconstruction allows the exploration of possibilities within a space (Boden, 2004; Veale et al., 2019). These cognitive mechanisms include divergent thinking as well as analytical thinking. Human cognitive mechanisms can inspire AI programs. Inversely, new search strategies for humans may be inspired by AI algorithms. The collaboration

between AI and creators is another promising avenue of research (e.g., Anantrasirichai & Bull, 2022).

Computational sciences and AI can be used to verify the theory and improve it. The CST defines ten cognitive spaces which are assumed necessary to cover the entire range of human experiences. If each space of the CST truly exists, then AI specific to each of them could be developed. We already witnessed the capacity of AI systems to explore and exploit the *image* space, with tools such as Dall-E, Stable Diffusion, and MidJourney; or the *movement* space with robots made by companies such as Boston Dynamics. The *sound* space has been tackled by tools such as MusicLM. In addition, Chat-GPT exploits the *network* space by using weighted associations to predict the optimal linguistic response to a prompt.

The advantage of formalizing psychological theories into computational terms lies in the fact that each concept must be very clearly defined — all ambiguities must be dissolved. For example, a *story character* is a psychological unit within the *story* space. A story character is a vague category which regroups archetypes such as “good guys” and “bad guys”. Translating “good guy” in computer terms requires to state explicitly which set of characteristics makes a good guy “good” instead of anything else (Finlayson et al., 2015). This type of rigorous definition for each unit and each space, and a consensus surrounding those definitions, is precisely what is needed to push the theory forward and falsify it (e.g., Farrell & Lewandowsky, 2010). This work will require many research teams considering the broad range of human experiences. Additionally, insights from artists will be invaluable, as they are known to delve deeply into some of the cognitive spaces.

Conclusion

This chapter provided an overview of a new theory of cognition called the Cognitive Space Theory. By combining the latter with theories of creativity, we investigated how educational systems could cultivate student's creative potential. In particular, we argued that the mastery of knowledge and skills, as well as the exploration of new possibilities, were both necessary to develop student's creative potential. Unfortunately, current educational systems tend to weigh mastery much more than exploration. This risk denaturalizes the learning process and prevent students from developing a personal and original approach to disciplines and topics.

The ten cognitive spaces defined by the CST suggested that some human experiences had been depreciated by most modern educational systems. This includes the emotion, strategy, and sensation (i.e., flavors, odors, and skin sensations) spaces, among others. We argued that an educational system based on the CST would have to recognize the value of the entirety of human experiences as being relevant in their own right. This is important to cultivate creative thinking and to develop a broad range of knowledge and abilities which can inspire new ideas and facilitate the adaptation to new constraints. Claims about the importance of arts in school sometimes reflect the view that arts are important not in themselves, but for how they support academic disciplines, such as how music improves mathematics or how visual arts improve geometry and spatial reasoning. In this chapter, we argued in favor of the transfer of knowledge from one discipline to another as a way to promote profound learning and cultivate creative thinking. As such, learning from science may transfer to arts, and vice-versa, with no preference for the direction. We are strongly in favor of replacing siloed approach to learning with a more integrative approach based on the cognitive spaces of the CST. Teaching for the underlying cognitive spaces allows to focus on the core element which unites various activities. Therefore,

although disciplines may change, evolve, and even disappear, teaching for the underlying cognitive space offers a stable agenda to master and explore the possibilities of the human mind throughout one's life. An integrative approach based on the CST and theories of creativity has the potential to 1) make learning opportunities explode for students and teachers, 2) value a greater variety of experiences, 3) make the exploration' component of the creative process more likely to be integrated in curricula, 4) reduce the tendency to grade in silo, 5) maintain a rigor of thinking throughout disciplines, 6) facilitate the transfer of learning, 7) develop students and teachers meta-cognition, 8) develop students creative potential, and lastly 9) enable more individuals to discover their life's passion.

A research agenda was proposed to test the theory and to accumulate evidence before implementing it into educational systems. This research agenda span from neuroscience to cognition, and up to AI. Kragel and colleagues (2018) were right in noting that all categories are ultimately psychological ‘‘constructs,’’ which we organize into taxonomies (or alternatively as ontologies; see Poldrack & Yarkoni, 2016). Notably, a recent initiative called the Cognitive Atlas started to build a psychological ontology, whereby the fundamental building blocks of human cognition would be systematically identified and organized (Poldrack & Yarkoni, 2016). A reorganization of mental constructs based on underlying causes, such as going from an organization of diseases based on their symptoms to an organization based on their biological causes, often leads to paradigm shifts and a burst of research productivity. An important contribution of the CST is its organization of the literature in psychology according to a limited set of fundamental cognitive spaces. This could contribute to the accumulation of knowledge and to reaching a greater consensus within the field. The rigorous definition of each psychological unit within each cognitive space is what will push the theory forward and falsify it. Thus, we

invite the contribution of all research teams as well as artists to this research agenda, considering the broad coverage of human experiences.

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