The DA VINCI Model for the Creative Thinking Process

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1 Introduction: The Central Role of the Process in Creativity

There are several frameworks for creativity studies, such as the 4P's (Rhodes, 1961), the 5A's (Glăveanu, 2013), or the 7C's model (Lubart, 2017). All of these frameworks encompass at least three fundamental dimensions: the creative process, the creative actor enacting the process, and the creative product as the outcome of the process. It can be argued that the core of the creativity phenomenon is undoubtedly the creative process. Without a creative process, the actor could not be engaged in creativity, and therefore there would be no creative outcome nor its consumption. The same line of reasoning applies even more strongly to the other dimensions contemplated by the 4P's, 5A's, and 7C's frameworks: they all rely intrinsically on the existence of a creative process. The opposite does not hold: for example, it is perfectly normal to have a creative process without having reached any creative outcomes: this might even be useful, for example in case creativity is used as a therapeutic mechanism (Hannemann, 2006).

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As a direct consequence, when creativity is considered, we should look for a definition that focuses on the creative process, and not on the possible creative outcomes of this process. Strangely enough, the standard definition of creativity (Runco & Jaeger, 2012), by foreseeing that creativity requires both originality and effectiveness, is actually focused on the existence of an outcome and on its assessment by some entity, who should recognize its originality and effectiveness in some specific knowledge domain. As discussed in Corazza (2016), this definition is insufficient as it leads to a static theoretical framework, missing all the dynamics of the creative process, which include long periods of creative inconclusiveness (Corazza, 2016), along with more rare occasions of creative achievement. Recognizing the central role of the creative process, it is therefore mandatory to adopt a dynamic definition of creativity (Corazza, 2016), foreseeing that creativity requires *potential* originality and effectiveness. The addition of a single word, potential, has the power to transform the theoretical framework from static to dynamic, and to shift the focus from creative products to creative processes (Botella & Lubart, 2019; Corazza, 2016, 2020; Corazza & Glaveanu, 2020).

Under the light of the dynamic definition of creativity, we can also provide a definition for the creative process. Lubart (2001) defined it as: "The sequence of thoughts and actions that leads to a novel, adaptive production", and this definition is still a derivative of the standard definition of creativity, for it does not contemplate the case in which the production is not (yet) reached, or its value is debatable. Therefore, we must provide a dynamic definition of a creative process, as "*A sequence of thoughts and actions aimed at the generation of outcomes with a potential for originality and effectiveness*". A fundamental part of the creative process will therefore reside in the active extraction of value from generated ideas, that we identify as creativity *estimation* as opposed to creativity assessment or judgment (Corazza, 2016, 2020).

Modeling the creative process has been an important topic for about a century in creativity studies (see Lubart, 2001, 2018, and the references therein). Any model must be interpreted as a metaphor, without any claim to represent 'reality' in a faithful way, but with different levels of usefulness that need to be justified. For the DA VINCI model presented in this Chapter, there are three levels of usefulness: (a) theoretical; (b) empirical; and (c) practical. First, from a theoretical point of view, the DA VINCI model is an important part of the Dynamic Creativity Framework descending from the dynamic definition of creativity cited above; the DA VINCI model is compatible with other models proposed in the literature, as discussed below, but it adds the important elements of Inspiration and divergent Creativity estimation. Second, understanding the creative process through the DA VINCI model can be used as a guide in the design and realization of empirical experiments for the study of creative cognition, creative motivation, idea generation, creativity estimation, and so on, to provide additional scientific data to confirm the validity of the model itself. Finally, the DA VINCI model can also be used as an educational tool for creativity training, as well as an application tool to guide practical sessions of idea generation. In this practical sense, the DA VINCI model can be used both by an individual and by a team of actors.

2 The DA VINCI Model for the Creative Thinking Process

Our model was initially identified as 'DIMAI' (Corazza & Agnoli, 2018; Corazza et al., 2014, 2016), and was renamed 'DA VINCI' in 2019, to dedicate it to the great Leonardo Da Vinci (1452–1519) in the year of the 500-th anniversary of his death. This dedication is well justified by the fact that Leonardo represents a unique testimonial for creativity, being the only human in history who was able to produce high level creative work in about twenty different disciplines, pertaining to the arts, science, and technology. The DA VINCI model is intended to describe the occurrence of a *creativity episode*, the time-extension of which is a-priori undetermined, due to its manifold dynamic extensions (Corazza, 2019, 2020). It must be clearly stated that there is no claim that this model actually reflects the approach that Leonardo followed in his creativity episodes, although some of the components of this model have been inspired by the lessons that can be learned from the Da Vinci codex. It is worth noting that DA VINCI has been turned into an acronym to help indexing the five key mental states that constitute the backbone of the model: DAV (Drive—Attention & Volition), I (Information), N (Novelty generation), C (Creativity estimation), I (Implementation).

The reason why we identify these main constituents of the DA VINCI model as 'mental states', as opposed to the more classic term 'stages' (e.g., see Wallas, 1926), is that multiple mental states can coexist at the same time in the mind of the creative actor. Therefore, even though the description of the DA VINCI model follows a linear and sequential order, its activation can be much more complex and non-linear, depending on meta-cognitive executive control. As an example, the DAV state, which contains the fundamental motivational elements allowing the actor to take risks and sustain possible frustrations, must remain active throughout the creative thinking process, in parallel with other mental states.

The graphical representation of the DA VINCI model is reported in Fig. 1. As can be seen, the three central mental states (I, N, C) contain each two components, representing a duality of modalities that will be explained later, but that in general reflects convergent vs. divergent modalities. At the output of the DAV, I, N, and C mental states, different forms of preliminary outputs are represented, feeding and creating an exchange between different mental states. These are, respectively: Refined Focus Area (RFA), Platform-Incubation, Raw Ideas, and Conceptual Prototype. Whereas the communication link is clearly visible between adjacent states, it can also be effective between non-adjacent mental states. For example, the RFA that links DAV and I states, also links DAV and C states, because as we will explain later convergent Creativity estimation is aimed at extracting value from the creative ideas with reference to the initial RFA. Further, it should be noted that all of the elements of the DA VINCI model are interconnected by paths that have no arrows. This is intended to show graphically that there is no single predetermined way to activate mental states, their modalities, and the corresponding outputs, but multiple sequences of activation can be generated within the DA VINCI model, corresponding to different thinking

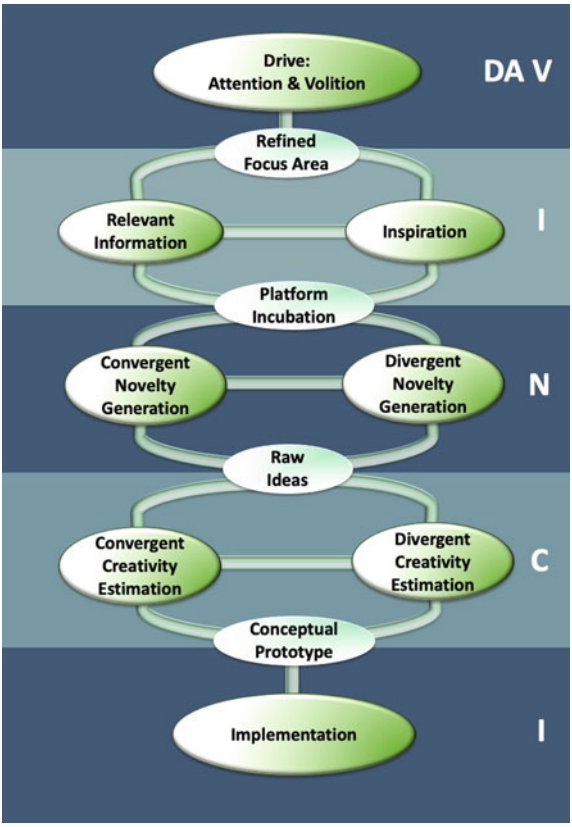

Fig. 1 The DA VINCI model for the creative thinking process

styles (to be discussed later) and/or different situations that may occur in the embedding environment. In fact, this process does not happen in isolation, but is influenced by all the interactions in which the creative actor engages.

As we will discuss later, the DA VINCI model is compatible with other models for the creative thinking process, but it also has two main peculiarities that make it well distinct: the component of Inspiration within the I (Information) mental state, and the component of divergent Creativity estimation within the C (Creativity estimation) state. Having given a general overview of the DA VINCI model, we now enter into the detailed description of the five mental states.

3 DAV: Drive—Attention & Volition

The basic behavior of a cognitive system supported by a non-pathological brain is guided by the minimization of energy expenditure. This is essentially the foundation of the *cognitive economy* assumption, which foresees as the main goal that

of conserving the finite available resources as much as possible (Rosch, 1978). In fact, the process of learning and reviewing produces a progressive reduction of energy expenditure in the brain, so that brilliant and fast responses to external or internal stimuli involve minimal energy consumption. This is a fundamental and adaptive neural and cognitive goal, that guarantees maximum survival time spans for a given level of nutrition. There are many mechanisms used by the neural and cognitive systems in order to achieve the goal of energy minimization, among which lowering thresholds of neurons, reduced activation of structures, habituation, attention focusing, and proactive prediction. All of these mechanisms work against the creative process, because they tend to lead rapidly towards the 'best', previously known, response.

As a consequence of the above fundamental observation, if a creativity episode is to begin at all, there is the necessity to invest an amount of energy and time which is far superior to the minimum necessary for mere survival. The Drive represents this mental state in which a willingness is (explicitly or implicitly) activated in the creative actor to actually make this investment of energy and time, taking the risk to engage in an activity without a-priori guarantees of the possible outcomes. Without this Drive, creativity remains stifled and unable to be expressed, as thinking always remains within the comfortable boundaries of previous knowledge.

In the DA VINCI model, it is explicitly recognized that the creative Drive stands on two pillars: cognitive (Attention) and motivational (Volition). The cognitive element involves the definition of an area of attentive focus (Focus Area) for the creativity episode, which might be an assigned creative task, a problem to be solved (in this case, the literature of interest speaks of Problem Discovery, Problem Definition and Re-definition, Problem finding; Guilford, 1967; Mumford et al., 1991), but also an area to be explored, without any evident problem to be solved. This third possibility promotes engagement in a much wider range of creativity episodes. The Drive in Attention involves spending energy and time to look at the Focus Ares from many different points of view, which is key to combat fixation and selectivity of attention. The ability to broaden the attentional focus while defining the creative focus emerged as an attribute of creative individuals, especially when associated with the Openness personality trait (Agnoli et al., 2015). In fact, flexible perspective taking is a fundamental ability to be trained in order to improve creative performance. In terms of problem solving, this is referred to as problem re-definition (Reiter-Palmon & Illies, 2004), which can be shown to be predictive of creative success.

On the other hand, the creative Drive is not only a matter of pure cognition. In fact, the motivational elements are as important, if not more. As we recently stated, motivation and emotions can be defined as the spinal cord of the overall creative thinking process, or as the necessary (but not sufficient) condition for the creative process to occur (Agnoli & Corazza, 2019). Volition, or the willingness to engage in the creativity episode, is actually the source of the excess energy in the Drive. Volition is known to have both intrinsic and extrinsic components (Amabile, 1993), depending on whether they come from within the creative actor or from the surrounding environment, such as for example a boss asking for creative ideas to solve a company's problem. The best condition corresponds to the case in which intrinsic and extrinsic

motivation resonate: imbalance is in general an inferior condition, either when the actor is motivated but the environment works as an obstacle, or when the environment is favorable but the actor does not show any interest. This interaction between intrinsic and extrinsic motivation emerged clearly in a recent exploration of creative achievement within the educational environment, where the highest achievement scores were obtained by individuals characterized by high openness and high levels of both motivational sources (Agnoli et al., 2018).

A neurological parallel to Volition can be found in the creative Drive model proposed by Flaherty (2005). This author offered an alternative neurological explanation to creativity as opposed to the lateralization model for creativity skills proposed by Martindale (1999). In particular, Flaherty suggested the term "creative drive" for explaining the result of the interaction between temporal and frontal lobes and the limbic system. She argued that most neurological models have focused on creative cognition skills, but the drive, as sustained by the limbic system, is neurally independent from these skills, and probably more important for explaining creative achievement. More recent models have been proposed for the neurological explanation of this state (see Khalil et al., 2019), all pointing at relatively independent neurophysiological patterns for the drive sustaining the creative process.

Further empirical evidence for the role of basic neural motivational systems in the creative thinking process comes from the study of the functions of the dopaminergic systems on the generation of new ideas (Boot et al., 2017; Nijstad et al., 2010; Zabelina et al., 2016), with recent data showing that higher activation of the striatal dopaminergic system is predictive of higher originality when supported by higher flexibility of thought (Agnoli et al., 2021).

Now, Attention and Volition interact in the selection of the output of the Drive mental state, that is the Refined Focus Area (RFA). In other words, as the actor is exercising his/her ability to see the area of focus under many different points of view, the visited alternatives produce an effect on the willingness to engage in the creativity episode. If the selected RFA corresponds to the focus definition that is felt (perhaps based on instinct) to have the highest potential for originality and effectiveness (Corazza, 2016), then interest for this focus area will grow (Agnoli & Corazza, 2019), motivation will be highest, and the Drive will be most effective. This ideal condition is not always achieved, as the level of Drive will vary on a continuum. Finally, it should be noted that a list of possible RFAs can also be formed, but the alternatives must be explored one at a time, unless the creative process involves parallel teams.

4 I: Information

The creative episode aimed at a specific RFA is fed by information that is deemed to be important and necessary in that RFA knowledge domain. In the DA VINCI model, we refer to this as Relevant Information, represented in Fig. 1 as the convergent modality of the Information mental state. Here, convergence is intended towards

the knowledge domain of the RFA. Relevant Information must always be available to feed the creative process; basically, it comes from the knowledge and culture previously possessed or purposely acquired by the actor regarding the RFA. Relevant Information shapes the way in which the actor sees or perceives the RFA. Different levels of expertise in an area correspond to the amount of Relevant Information the individual has at his/her disposal.

Expertise involves the acquisition, storage and use both of explicit knowledge of the domain (facts, ideas, principles, etc.) and of tacit knowledge of the field (Ericsson & Smith, 1991; Reilly, 2008; Sternberg, 1998). Expertise is a process of continual, life-long development (Reilly, 2008). Experts are characterized by specific thinking mechanisms, such as rapid performance of procedures, well organized, interconnected and easily accessible knowledge structures, as well as superior short and long term memory and rich repertoires of strategies for problem-solving (Ericsson & Smith, 1991; Glaser & Chi, 1988; Johnson, 1988). As proposed by Reilly (2008), experts tend to work forward from given information to implement strategies for finding unknowns.

However, past research demonstrated that exceptional creators are not merely extreme experts in their domains (Simonton, 1996, 2000). Even if experts are superior than novices in well-defined problems, it has been demonstrated that in domains of much uncertainty experts fail to do better than novices (Johnson, 1988). Indeed, it is a known fact that major creativity leaps often come from novel members or from the periphery of a field (Cattani & Ferriani, 2008). On the other hand, without any Relevant Information one would be missing the fundamental ingredients in the creative process, which would be stifled at its start. This is the reason why small children, who may be undoubtedly very creative, cannot however compose music (with a few famous exceptions of unique giftedness) or invent the next technological device.

Relevant Information in an RFA can include many categories of semantic entities: dominant ideas in a field, theories, best practices, constraints, requirements, assumptions, historical and current facts, archives, future trends, past errors to be avoided, information gathered by interviews, customer briefs, activities by competition, problems to be solved, desires to be satisfied, etcetera. Clearly, the RFA itself is a very important element of Relevant Information, and the way it is specified can lead towards certain areas of exploration and hide others. More generally, Relevant Information includes all those semantic entities that constitute the way in which the RFA is perceived and understood according to the cultural state-of-the-art. Sufficient time and energy should be spent in the creative process to gather, select, and structure Relevant Information, and several methods can be introduced in order to make this step more efficient, such as for example the use of persona (Johansson & Messeter, 2005) that represents an idealized version of a person/user with interest in the RFA, with the purpose of better visualizing its needs and desires. Gathering and structuring Relevant Information is a strictly domain-specific activity, because it will change considerably if the RFA is, for example, composing a piece of music or designing a new product.

However, Relevant Information is not the only ingredient of the creative process. One of the most peculiar characteristics of the DA VINCI model, perhaps its most important difference with respect to other models, is that it also contains a specific component aimed at the introduction of *Inspiration* in the creative process, represented as the divergent modality of the Information state in Fig. 1. Inspiration should be intended essentially as information that a-priori does not appear to be strictly relevant to the RFA, or even purely irrelevant, paradoxical, absurd, incorrect. Therefore, if one were to follow a strictly rational approach to the generation of ideas related to the RFA, irrelevant information would have to be discarded, because it would act as a distraction. On the other hand, the thinking style in a creative process will include non-linearity, unusual associations, surprising interpretations, unexpected insights, original alternatives. For these, the introduction of an Inspiration in the form of irrelevant information (Agnoli et al., 2015, 2019) turns out to be crucial, in conjunction with personality characteristics: in fact, in the presence of sufficient Openness (Agnoli et al., 2015: Corazza & Agnoli, 2020), these elements of Inspiration can be processed along with the RFA and Relevant Information in order to create a state of mind that the actor has never visited before. We identify this state of mind as the Platform (see Fig. 1), which is the starting condition for Novelty generation to follow. Previous literature has pointed out that creative achievement could be related to the tendency to focus on irrelevant or discrepant facts (see for example the use of analogy in Dunbar's explanation of scientific thinking; Dunbar, 1995). Alissa (1972) stated that individuals who use a wider range of information, even if sometimes apparently irrelevant, tend to produce more creative products. More recently, empirical results demonstrated that the ability to focus attention also on apparently irrelevant information, which is typical of open-minded individuals, leads to a higher creative performance and creative achievement (Agnoli et al., 2015).

In essence, the role of the Inspiration component is to increase the probability that the Platform will be out of the common knowledge domain, or out-of-the-box. This greatly increases the potential for originality and effectiveness of the creative process: in fact, if all of the process remains within the high walls of existing knowledge, the probability to generate original ideas is in general quite low. There are many practical ways for introducing Inspiration in the creative process, such as for example the inventive principles of the TRIZ methodology (Altshuller, 1984), the SCAMPER approach (Serrat, 2017), or the Generative Modifiers (or Divergent Modifiers) of the Marconi Institute for Creativity (Corazza et al., 2015). It should be noted that the Platform can remain active in the creative process for a long period of time, even below the level of awareness of the actor, particularly in the case that the RFA contains very difficult problems to be solved. We identify this period as Incubation (see Fig. 1), and it is known that Incubation can lead to insight in creative problem solving (Gilhooly, 2017), as famously noted by Henri Poincaré (Corazza & Lubart, 2019; Poincaré, 1914).

5 N: Novelty Generation

The first objective in the generation of ideas is to produce authentic novelty. This will only lead to originality if an element of surprise can be identified; in other words, novelty is a necessary but not sufficient condition to generate originality (Corazza, 2016). As discussed before, bringing the Platform out of the common knowledge domain is essential to increase the potential for originality in the Novelty generation state, by processing the a-priori irrelevant information brought in through Inspiration (Agnoli et al., 2015, 2019). As well known from the creativity studies literature, Novelty generation entails two fundamental and dual modalities: convergent vs. divergent.

Convergent Novelty generation, or convergent thinking, consists in taking all the available inputs (RFA, Relevant Information, Inspiration) and moving towards a creative synthesis, a single output achieved by integration (Lubart et al., 2013). In case the RFA contains a problem, convergent Novelty generation works to find a solution, possibly a creative solution. In case the RFA is an area to be explored, convergent Novelty generation works to find a combination of the available inputs which is difficult to predict a-priori, and therefore novel and surprising. Achieving originality typically entails a use of the available inputs which goes beyond simple juxtaposition, but rather involves the emergence of a new reality which is more than the sum of the inputs. Here, a clear parallel to the phenomenon of emergence in complex systems can be seen (Sawyer, 1999). From a graphical point of view, convergent Novelty generation can be seen as a cone that takes many inputs and produces a single output. From a metaphorical perspective, it can be seen as climbing a mountain peak, with many possible routes and only one ‘solution’.

Divergent Novelty generation, or divergent thinking, being dual to convergent thinking, is aimed at producing a large number of alternative outcomes starting from a common root, that we identify as the Platform (Guilford, 1967). Tasks designed to measure divergent thinking performance are one of the most frequent approaches in empirical creativity studies, sometimes leading to the mistake of confusing divergent thinking for the creative process. Three parameters are typically associated to divergent thinking performance: fluency, flexibility, and originality.

Fluency corresponds to quantity, that is the number of generated alternatives. It is a peculiarity of the creative thinking process that quantity might lead to quality: in fact, the level of originality is not uniform across the responses, because high originality is rare and remote. Therefore, large fluency is crucial to have high potential originality. Also, this implies that in the measurement of divergent thinking performance average originality scores are not really significant: we are looking for those few outliers that stem out for their originality.

Lack of flexibility refers to the fact that, even if one shows very large fluency, all the alternatives could belong to a narrow semantic field. For example, if one is looking at alternative uses for a brick (a classic question in the Alternative Uses Test, Guilford, 1967), one could think of it as a tool to break a window, a door, someone’s head, to crack a nut, a chestnut, etcetera. As can be seen from this simple example, all

these alternatives share strong similarity, as they belong to the same semantic category of 'breaking objects'. Flexibility is therefore the ability to visit many semantic categories in the course of divergent Novelty generation. High flexibility is desirable, as it also increases the potential for originality, which is the ultimate goal. The importance of flexibility has been confirmed by Acar and colleagues (Acar et al., 2019); on the other hand, flexibility requires a higher investment of mental energy, due to the increase of neural activity in several brain regions associated with the changes of semantic category (Mastria et al., 2021).

Response originality, which comprises novelty, surprise, and authenticity (Corazza, 2016), is perhaps the most important performance parameter in a divergent thinking test, and one that is not simple to measure (Reiter-Palmon et al., 2019). For this purpose, there exist both objective methods, based on statistical infrequency (Wallach & Kogan, 1965), and subjective methods, such as the consensual assessment technique (CAT, Amabile, 1982). Given the emphasis on fluency and large samples in empirical studies, the problem of assessing originality can become cumbersome; for this reason, recent efforts have been geared toward the automation of originality scoring (Beaty & Johnson, 2021).

Finally, it should be noted that divergent thinking is an iterative process, in which an already produced alternative must be inhibited in order for the next one to be generated. Therefore, in a creative process exploiting divergence, inhibition is as important as elicitation. The first response to be inhibited corresponds to the most common response, the one typically associated with being correct and 'intelligent'. This inhibitory behavior clearly emerged in a recent neurophysiological study on the temporal occurrence of originality in the brain activity (Agnoli et al., 2020), where the first most obvious response is recovered from the memory system (with an evident activity in the frontal brain regions), whereas starting from the second response memory is inhibited in order to elicit an imaginative and integrative activity (with an evident activity in the parietal and temporal regions). When Binet defined intelligence, he referred to it as 'the ability to inhibit the instinct response' (Goddard, 1946). Here we can say that the creativity component of divergent Novelty generation entails a second level of inhibition: not only the instinct, but also the intelligent response must be inhibited in order to generate divergent alternatives.

At the output of convergent and divergent Novelty generation activities, a certain number of Raw Ideas will be available (see Fig. 1). These will in general need refinement, essentially because the more an idea is original, the more difficult it is to see its value. This is the purpose of the next state of mind, Creativity estimation.

6 C: Creativity Estimation

In the dynamic creativity framework (DCF), based on the dynamic definition of creativity (Corazza, 2016, 2020; Corazza & Lubart, 2020), it is crucial to avoid the mistake of considering the assessment of ideas as static judgment, as categorization, or as a simple scoring procedure. Even though all these activities are possible, and

perhaps necessary when performing empirical experiments in creativity studies, they carry as a consequence the end of the creative thinking process. But this would be very far from optimal: the extraction of all the potential effectiveness from Raw Ideas is an active process, definitely non-obvious, which we identify as Creativity estimation. The word estimation (Corazza, 2016) was purposely introduced to hint at the fact that this mental state is affected by both objective and subjective elements, and therefore an absolute judge for creative ideas does not exist. Although this might be seen as a problem in empirical experiments, especially in view of the consensual assessment technique mentioned before, it is actually a source of richness in terms of the potential for originality and effectiveness of the creative process. Recent research indeed demonstrated that taking into account the subjective emotional state of the judges engaged in CAT scoring of an AUT task, it was possible to explain a source of variability in the scoring of alternative ideas (Mastria et al., 2019).

It can be argued that a good part of the art of the creative process resides in the subjective ability to see the value (artistic, scientific, practical) in ideas that everyone else consider to have no value. Creativity estimation includes clearly the simple assessment or scoring of ideas, but it can go well beyond that to lead to dynamic refinement of the Raw Ideas (Corazza, 2020, 2016). It is very interesting to note that also in this state, both convergent and divergent modalities are foreseen, but with quite a different meaning.

Convergent Creativity estimation corresponds to the action of trying to extract the maximum value from a Raw Idea while making reference to the selected RFA. In other words, the objective is to see how the idea under consideration can be formulated or evolved in order to enlarge its originality with respect to the state-of-the-art in the RFA, as well as its effectiveness in terms of providing a solution, satisfying a need, or in general providing aesthetic, scientific, or practical value within the boundaries of the RFA. It can be stated that convergent Creativity estimation is the classic state of mind one would expect at this stage, in particular for creative problem solving.

On the other hand, we also foresee the possibility of divergent Creativity estimation, another peculiarity of the DA VINCI model. This corresponds to the case in which the actor is allowed to extract the value from a Raw Idea above and beyond the initial RFA, by imagining different environments, different fields of application or of knowledge. The reason why this unconventional step holds very significant potential is that the actual value of an idea might not reside in the initial focus, but perhaps in a totally different and unforeseen area. In extreme cases, an outcome could be considered a total failure with respect to the initial RFA, and as such it should be discarded, but it might turn out to be an extremely successful creative disruption from a different perspective. An example is in order: as reported in (Glăveanu & Gillespie, 2014; Karapapa, 2019) the invention of the post-it notes came out from a failed design of a super-strong glue by Spencer Silver. The weak glue he generated by experimenting on a new family of polymers remained in a state of creative inconclusiveness for about ten years, also identified as ‘a solution looking for a problem’. Fortunately, instead of completely throwing away the idea, a form of divergent Creativity estimation was enacted by someone else, Arthur Fry, who devised a different use for this

adhesive to hold a bookmark in place, which led to one of the most successful products for meetings and teamwork (Karapapa, 2019). Whenever the creative process is pushed towards the search for high potential originality, it is not unusual to see that one has generated some ideas with properties that were not initially sought. In other words, divergent Creativity estimation is the home of serendipity (Ross & Vallée-Tourangeau, 2021).

When as an outcome of convergent and divergent Creativity estimation many refined ideas are extracted, it will be necessary to proceed to form a short-list and a selection. The top idea(s) might then be transformed into a prototype (see Fig. 1), in order to test actual effectiveness, perhaps by involving external actors. This is the purpose of the next state, Implementation.

7 I: Implementation

The final goal of the process for a given creativity episode is in general subject to discussion: in the DA VINCI model, we consider that the process cannot be successfully concluded unless some form of Implementation of at least one idea occurs, leading to a process of innovation. Otherwise, the process would be reduced to some form of mental exercise, which certainly has its own value, but with scarce practical bearing. Carrying at least one idea to actual Implementation is therefore a crucial part of the process, that can take on many forms. Implementation involves the highest interaction with the outside world.

The most basic form of Implementation, but a very important one nonetheless, is to prepare a presentation of the idea for an audience. Indeed, the higher the originality of a creative idea, the stronger the resistance that the outside world will generally offer against it. This is because the state-of-the-art exists for good reasons, and it tends to grow incrementally instead of leaping towards creative disruptions. As a consequence, if one wants to bring any creative idea to success, it is of fundamental importance to be able to persuade an audience of the potential benefits and advantages. For the same idea, a good vs. bad presentation to a critical audience might lead to success vs. failure.

Presuming that a successful presentation of an idea has taken place, the Implementation state foresees actual realization under constraints. In particular, Implementation is constrained by two different kinds of factors: 1. intrinsic constraints, i.e., factors that are strictly related to the idea characteristics (e.g., time to bring the idea to reality, money needed to realize the idea, knowledge to be acquired, etc.); and 2. extrinsic constraints, i.e., factors that highly influence idea realization, mostly related to the individual's social environment, such as cultural rules, dominant ideas, experts opinions, etcetera. Moreover, a third factor plays a central role during the implementation state, determining the success of idea Implementation: individual personality. Creative self-beliefs, self-identity, grit and persistence all play a fundamental role in the process of bringing a creative idea to a successful realization (Karwowski & Kaufman, 2017).

The ability to resist the frustration caused by critical remarks or rejection of one's idea coming from an external audience is a fundamental characteristic of a creative actor, largely influencing the potential for a successful Implementation and therefore for creative achievement. Trait emotional intelligence, including the attitude to successfully manage negative emotions emerging from frustration, has been demonstrated to be essential in order to persist in the creative process, possibly refining previous ideas to implement more original solutions (Agnoli et al., 2018).

8 Comparisons Between DA VINCI and Other Models

First, let's compare the DA VINCI model with its five mental states to the general three-stages model discussed in Corazza and Agnoli (2015), which foresaw: (a) gathering and structuring of information elements; (b) ideation; and (c) verification of the effects. The mapping appears to be quite simple: in the DA VINCI model, stage (a) is represented by the Information state; stage (b) is represented by the Novelty generation state; stage (c) is represented by a combination of the Creativity estimation and Implementation states. Clearly, the DA VINCI model adds very important elements, such as the DAV state and much more detailed descriptions of the relevant components at the different stages, with the specificities of the Inspiration and divergent Creativity estimation components.

Undoubtedly, one of the most famous models of the creative thinking process is the one by Wallas (1926), which was actually inspired by the writings of Henri Poincaré (1914, Corazza & Lubart, 2019). Wallas' model foresees four stages: Preparation, Incubation, Illumination, and Verification. Whereas the difference between 'stages' and 'mental states' should be underlined, it is at any rate possible to map these four stages onto the states of the DA VINCI model. Preparation maps onto both DAV and I states; Incubation occurs at the border between the I and N states (see Fig. 1); Illumination is a subset of the N state (because not all ideas are generated by insight); finally, the Verification stage is a part of the Implementation state. Clearly the DA VINCI model emerges as an advancement with respect to Wallas' by introducing subprocesses and components of the creative process, as suggested by Lubart (2001), the concept of mental states as opposed to stages, the distinction between convergent and divergent modalities, and the multifold creative styles that will be discussed in the next section.

Mumford et al. (1991) introduced an eight stage model: (i) problem construction, (ii) information encoding, (iii) category search, (iv) specification of best fitting categories, (v) combination and reorganization of category information to find new solutions, (vi) idea evaluation, (vii) implementation of ideas, and (viii) monitoring. In terms of the DA VINCI model, stage (i) is mapped onto DAV, stages (ii, iii, iv) all refer to the I state, in its Relevant Information component (Inspiration was not foreseen in Mumford et al., 1991), stage (v) corresponds to the N state, stage (vi) to the C state, and finally stages (vii, viii) are mapped onto the Implementation state. The DA VINCI model extends the reach of Mumford's model by allowing the RFA

to represent not a problem but an area to be explored, by introducing irrelevant information as a key form of Inspiration, by introducing mental states in place of stages, and by allowing divergent Creativity estimation to include serendipitous findings.

Finally, we consider the Geneplore model (Finke et al., 1992), which includes two fundamental stages that are visited in an iterative fashion: Generation of pre-inventive structures and Exploration of their effectiveness. The iteration is controlled by the intrinsic or extrinsic Constraints of the problem or the area. This model can also be mapped onto the DA VINCI model: Generation corresponds to the N state, and Exploration is mapped onto the C state, between which it is possible to iterate indefinitely. The Constraints in the Geneplore model can be mapped onto the boundaries produced by the RFA as well as the Relevant Information of the DA VINCI model. It is evident that the DA VINCI model represents a much more complete vision of the creative process, with respect to what Geneplore can offer.

Other models for the creative thinking process (Lubart, 2001) could be considered and mapped onto DA VINCI in a similar fashion. As a consequence, we argue that the DA VINCI model is able to cover all of the previously introduced models for the creative thinking process, but it also adds important elements that could not be found in preceding proposals, at least explicitly: the Inspiration component inside the Information state, and the divergent component in the Creativity estimation state. Notably, these two additional elements are both characteristic and critical in the creative thinking process.

9 Creative Styles in the DA VINCI Model

As noted by Botella and Lubart (2019), when the creative process is enacted in domains as different as the arts, design, or science by different individuals, many variations on the theme should be expected, and the possible sequence of thoughts and actions that are followed can appear to be quite diversified and complex. In short, many different creative styles are possible, and it might seem to be difficult for a single creative process model to be representative of all possible styles. However, it is possible to show that the DA VINCI model, with its structure, absence of arrows, possibility to iterate, and use of dual components, contains a very large number of different trajectories, corresponding to many different creative styles.

The two fundamental styles contained in the DA VINCI model correspond to a sequential visit to the five mental states of DAV, I, N, C, I maintaining either a convergent (left side) or a divergent (right side) style of thinking. We identify these respectively as the ‘problem solver style’, and the ‘free explorer style’. If an actor adopts a problem solver style (left side of the DA VINCI model): the RFA will correspond to the problem to be solved, possibly ill-defined; in the I state, only Relevant Information will be collected; in the N state, convergent Novelty generation will be pursued to find possible solutions to the problem at hand; in the C state, convergent Creativity estimation will be adopted to verify whether the solution is

potentially original and effective; finally, in the Implementation state the solution will be brought to reality to instantiate innovation.

In contrast, if an actor adopts a free explorer style: the RFA will be a loosely defined area to be explored, perhaps one that only a few others are considering; in the I state, irrelevant information will be allowed to enter as a form of Inspiration (along with the always present Relevant Information), leading to Platforms that might be very far out from the common knowledge domain; in the N state, divergent Novelty generation will be enacted to give multiple alternative interpretations of the Platform; in the C state, divergent Creativity estimation will be allowed to see all the possible implications of the alternative interpretations produced in the N states, within the RFA but also beyond it, out of which one (or more) will be selected for actual Implementation. It should be clear that the free explorer style is much more time- and energy-consuming than the problem solver style, but its potential for originality and effectiveness is also higher.

The richness of the DA VINCI model comes from the fact that it allows all possible intermediate styles that can exist between the extremes of the problem solver and free explorer styles. In fact, the creative actor can move from the left side to the right side of the DA VINCI model, and vice versa, at any moment he or she wishes to do so. Including the domain specificity of Relevant Information and the possibility for multiple iterations, that can occur also between non-adjacent mental states (for example, between the C state and the DAV state: as the actor is extracting value, the RFA gets modified and Volition might be enhanced or depressed), it should be evident that the variations on the theme within the DA VINCI model are abundant.

10 Conclusion

In this chapter, we have presented the DA VINCI model for the creative process, as composed of five fundamental mental states: DAV (Drive: Attention and Volition), I (Information), N (Novelty generation), C (creativity estimation), and I (Implementation). One of the most interesting questions raised by Lubart (2001) in his analysis of the past, present, and future of models for the creative process was the following: What makes a creative process *creative*? In other words, what are the distinctive elements of a creative process with respect to any other form of cognitive process that does not lead to outcomes that are potentially original and effective?

This question is relevant not only from the point of view of understanding the creativity construct per se, but also for putting it in perspective with respect to the intelligence construct, as proposed in Corazza and Lubart (2020, 2021) and Corazza et al. (2021a, 2021b) by introducing the concept of the space–time continuum. Finding a balance between intelligence and creativity is a crucial objective in all human endeavors. We believe that the DA VINCI model can provide several useful indications in trying to provide answers to the fundamental question raised by Lubart (2001).

First, the creative process is characterized by a Drive, i.e., excess expenditure of energy and time with respect to the minimum that would be necessary to provide a correct (intelligent) response. Second, the creative process allows the entrance of inspiration, in the form of irrelevant information that would normally be discarded in an intelligent thinking process, the purpose of which is to create mental states that are rare and far from the state-of-the-art. The idea generation state is then launched from this platform. Third, the creative process is characterized by convergent and divergent novelty generation approaches, the purpose of which is to let ideas *emerge* in an a-priori unpredictable way, instead of being the result of a rational progress of thought. Fourth and final, the creative process is characterized by both convergent and divergent creativity estimation styles, that allow not only to be coherent with one's initial purposes, but also to discover and welcome serendipitous findings.

Several empirical results have been presented in this manuscript to support the introduction of different elements of the DA VINCI model, but there are clearly many open avenues for other empirical studies to confirm various elements of this model of the creative process, which represents one of the most complex constructs of the human mind. We hope that these avenues will be the subject of future research endeavors in the creativity studies community.

References

Acar, S., Alabbasi, A. M. A., Runco, M. A., & Beketayev, K. (2019). Latency as a predictor of originality in divergent thinking. *Thinking Skills and Creativity, 33*, 100574.

Agnoli, S., & Corazza, G. E. (2019). Emotions: The spinal cord of the creative thinking process. In R. Beghetto & G. E. Corazza (Eds.), *Dynamic Perspectives on Creativity* (pp. 47–65). Springer.

Agnoli, S., Franchin, L., Rubaltelli, E., & Corazza, G. E. (2015). An eye-tracking analysis of irrelevance processing as moderator of openness and creative performance. *Creativity Research Journal, 27*(2), 125–132.

Agnoli, S., Franchin, L., Rubaltelli, E., & Corazza, G. E. (2019). The emotionally intelligent use of attention and affective arousal under creative frustration and creative success. *Personality and Individual Differences, 142*, 242–248.

Agnoli, S., Mastria, S., Zanon, M., & Corazza, G. E. (2021, April 13). Dopamine supports idea originality: The role of spontaneous eye blink rate on divergent thinking. *PsyArXiv*. April 13. https://doi.org/10.31234/osf.io/rfgu4

Agnoli, S., Runco, M. A., Kirsch, C., & Corazza, G. E. (2018). The role of motivation in the prediction of creative achievement inside and outside of school environment. *Thinking Skills and Creativity, 28*, 167–176.

Agnoli, S., Zanon, M., Mastria, S., Avenanti, A., & Corazza, G. E. (2020). Predicting response originality through brain activity: An analysis of changes in EEG alpha power during the generation of alternative ideas. *NeuroImage, 207*, 116385.

Alissa, I. (1972). Stimulus generalization and over-inclusion in normal and schizophrenic subjects. *Journal of Clinical Psychology, 34*, 182–186.

Altshuller, G. (1984). *Creativity as an exact science*. Gordon and Breach.

Amabile, T. M. (1982). Social psychology of creativity: A consensual assessment technique. *Journal of Personality and Social Psychology, 43*, 997–1013.

Amabile, T. M. (1993). Motivational synergy: Toward new conceptualizations of intrinsic and extrinsic motivation in the workplace. *Human Resource Management Review, 3*(3), 185–201.

Beaty, R. E., & Johnson, D. R. (2021). Automating creativity assessment with SemDis: An open platform for computing semantic distance. *Behavior Research Methods, 53*(2), 757–780.

Boot, N., Baas, M., van Gaal, S., Cools, R., & De Dreu, C. K. (2017). Creative cognition anddopaminergic modulation of fronto-striatal networks: Integrative review and researchagenda. *Neuroscience & Biobehavioral Reviews, 78*, 13–23.

Botella, M., & Lubart, T. (2019). From dynamic processes to a dynamic creative process. In R. A. Beghetto & G. E. Corazza (Eds.), *Dynamic Perspectives on Creativity* (pp. 261–278). Springer.

Cattani, G., & Ferriani, S. (2008). A core/periphery perspective on individual creative performance: Social networks and cinematic achievements in the Hollywood film industry. *Organization Science, 19*(6), 824–844.

Corazza, G. E. (2016). Potential originality and effectiveness: The dynamic definition of creativity. *Creativity Research Journal, 28*(3), 258–267.

Corazza, G. E. (2019). The dynamic universal creativity process. In R. A. Beghetto & G. E. Corazza (Eds.), *Dynamic perspectives on* (pp. 297–319). Springer.

Corazza, G. E. (2020). Dynamic creative process. In M. Runco & S. Pritzker (Eds.), *Encyclopedia of creativity* (3rd ed., Vol. 1, pp. 400–405). Elsevier.

Corazza, G. E., & Agnoli, S. (Eds.). (2015). *Multidisciplinary contributions to the science of creative thinking.* Springer.

Corazza, G. E., & Agnoli, S. (2018). The creative process in science and engineering. In T. Lubart et al. (Eds.), *The creative process: Perspectives from multiple domains* (pp. 155–180). Palgrave Macmillan. https://doi.org/10.1057/978-1-137-50563-7_6

Corazza G. E., & Agnoli (2020). Personality: Openness. In Runco, M. A., & Pritzker, S. R. (Eds.), *Encyclopedia of creativity* (3rd ed., Vol. 2, pp. 338–344). Elsevier, Academic Press.

Corazza, G. E., Agnoli, S., & Martello, S. (2014). Counterpoint as a principle of creativity: Extracting divergent modifiers from The Art of Fugue by Johann Sebastian Bach. *Musica Docta, 4*, 93–105.

Corazza, G.E., Agnoli S., & Martello S. (2016). Introducing irrelevant information in the creative process: The DIMAI model for fashion design. In *Cultures, Fashion, and Society Notebooks 2015* (1–15). Pearson – Bruno Mondadori.

Corazza, G. E., Darbellay F., Lubart T., & Panciroli C. (2021a) Developing intelligence and creativity in education: Insights from the space–time continuum. In S. Lemmetty, K. Collin, V. P. Glăveanu, P. Forsman (Eds.), *Creativity and Learning*. Palgrave Studies in Creativity and Culture. Palgrave Macmillan. https://doi.org/10.1007/978-3-030-77066-2_4

Corazza, G.E., & Glăveanu, V. P. (2020). Potential in creativity: Individual, social, material perspectives, and a dynamic integrative framework. *Creativity Research Journal*, *32*(1), 81–91.

Corazza, G. E., & Lubart, T. (2019). Science and method: Henri Poincaré. In V. P. Glaveanu (Ed.), *The creativity reader* (pp. 33–47). Oxford University Press.

Corazza, G. E., & Lubart, T. (2020). The Big Bang of originality and effectiveness: A dynamic creativity framework and its application to scientific missions. *Frontiers in Psychology, 11*, 2472.

Corazza, G. E., & Lubart, T. (2021). Intelligence and creativity: Mapping constructs on the space-time continuum. *Journal of Intelligence, 9*(1), 1.

Corazza, G. E., Reiter-Palmon, R., Beghetto, R., & Lubart, T. (2021b). Intelligence and creativity in the space–time continuum for education, business, and development. *Journal of Creativity*, *31*, 100003.

Dunbar, K. (1995). How scientists really reason: Scientific reasoning in real-world laboratories. In R. Sternberg & J. Davidson (Eds.), *Mechanisms of insight* (pp. 365–395). MIT Press.

Ericsson, K., & Smith, J. (1991). Prospects and limits of the empirical study of expertise: An introduction. In K. Ericsson & J. Smith (Eds.), *Toward a general theory of expertise: Prospects and limits* (pp. 1–38). Cambridge University Press.

Finke, R. A., Ward, T. B., & Smith, S. M. (1992). *Creative cognition: Theory, research, and applications.* MIT Press.

Flaherty, A. W. (2005). Frontotemporal and dopaminergic control of idea generation and creative drive. *Journal of Comparative Neurology, 493*, 147–153.

Gilhooly, K. J. (2017). Incubation, problem solving and creativity. In L. J. Ball & V. A. Thompson (Eds.), *The Routledge International Handbook of Thinking and Reasoning* (pp. 204–217). Routledge.

Glaser, R., & Chi, M. (1988). Overview. In M. Chi, R. Glaser, & M. Farr (Eds.), *The nature of expertise* (pp. 15–28). Erlbaum.

Glăveanu, V. P. (2013). Rewriting the language of creativity: The Five A's framework. *Review of General Psychology, 17*(1), 69.

Glăveanu, V. P., & Gillespie, A. (2014). Creativity out of difference: Theorising the semiotic, social and temporal origin of creative acts. In V. P. Glăveanu, A. Gillespie, & J. Valsiner, (Eds.), *Rethinking Creativity* (pp. 25–39). Routledge.

Goddard, H. H. (1946). What is intelligence? *The Journal of Social Psychology, 24*(1), 51–69.

Guilford, J. (1967). Creativity: Yesterday, today, and tomorrow. *Journal of Creative Behavior, 1*, 3–14.

Hannemann, B. T. (2006). Creativity with dementia patients. *Gerontology, 52*(1), 59–65.

Johansson, M., & Messeter, J. (2005). Presenting the user: Constructing the persona. *Digital Creativity, 16*(04), 231–243.

Johnson, E. (1988). Expertise and decision under uncertainty: Performance and process. In M. Chi, R. Glaser, & M. Farr (Eds.), *The nature of expertise* (pp. 209–228). Erlbaum.

Karapapa, S. (2019) Post-it note. In: C. Op den Camp, and D. Hunter, D. (Eds.), *A History of Intellectual Property in 50 Objects* (pp. 329–335). Cambridge University Press.

Karwowski, M., & Kaufman, J. C. (Eds.). (2017). *The creative self: Effect of beliefs, self-efficacy, mindset, and identity*. Academic Press.

Khalil, R., Godde, B., & Karim, A. A. (2019). The link between creativity, cognition, and creative drives and underlying neural mechanisms. *Frontiers in Neural Circuits, 13*, 18.

Lubart, T. I. (2001). Models of the creative process: Past, present and future. *Creativity Research Journal, 13*(3–4), 295–308.

Lubart, T. I. (2017). The 7 C's of creativity. *The Journal of Creative Behavior, 51*(4), 293–296.

Lubart, T. I. (Ed.). (2018). *The creative process: Perspectives from multiple domains*. Springer.

Lubart, T., Zenasni, F., & Barbot, B. (2013). Creative potential and its measurement. International *Journal for Talent Development and Creativity, 1*(2), 41–50.

Martindale, C. (1999). Biological bases of creativity. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 137–152). Cambridge University Press.

Mastria, S., Agnoli, S., & Corazza, G. E. (2019). How does emotion influence the evaluation of creative ideas? *Plos One, 14*(7), e0219298.

Mastria, S., Agnoli, S., Zanon, M., Acar, S., Runco, M., & Corazza, G. E. (2021). Clustering and switching in divergent thinking: Neurophysiological correlates underlying flexibility during idea generation. *Neuropsychologia, 158*, 107890.

Mumford, M. D., Mobley, M. I., Reiter-Palmon, R., Uhlman, C. E., & Doares, L. M. (1991). Process analytic models of creative capacities. *Creativity Research Journal, 4*, 91–122.

Nijstad, B. A., De Dreu, C. K., Rietzschel, E. F., & Baas, M. (2010). The dual pathway to creativity model: Creative ideation as a function of flexibility and persistence. *European Review of Social Psychology, 21*(1), 34–77.

Poincaré, H. (1914). *Science and method*. Original archived at Cornell University Library.

Reilly, R. C. (2008). Is expertise a necessary precondition for creativity? A case of four novice learning group facilitators. *Thinking Skills and Creativity*, *3*(1), 59–76.

Reiter-Palmon, R., Forthmann, B., & Barbot, B. (2019). Scoring divergent thinking tests: A review and systematic framework. *Psychology of Aesthetics, Creativity, and the Arts, 13*(2), 144.

Reiter-Palmon, R., & Illies, J. J. (2004). Leadership and creativity: Understanding leadership from a creative problem-solving perspective. *The Leadership Quarterly, 15*(1), 55–77.

Rhodes, M. (1961). An analysis of creativity. *Phi Delta Kappan, 42*, 305–310.

Rosch, E. (1978). Principles of categorization. In E. Rosch & B. B. Lloyd (Eds.), *Cognition and categorization* (pp. 27–48). Lawrence Erlbaum.

Ross, W., & Vallée-Tourangeau, F. (2021). Microserendipity in the creative process. *The Journal of Creative Behavior, 55*(3), 661–672.

Runco, M. A., & Jaeger, G. J. (2012). The standard definition of creativity. *Creativity Research Journal., 24*, 92–96.

Sawyer, R. K. (1999). The emergence of creativity. *Philosophical Psychology, 12*(4), 447–469.

Serrat, O. (2017). The SCAMPER technique. In O. Serrat (Ed.), *Knowledge Solutions* (pp. 311–314). Springer.

Simonton, D. K. (1996). Creative expertise: A life-span developmental perspective. In K. A. Ericsson (Ed.), *The road to expert performance: Empirical evidence from the arts and sciences, sports, and games* (pp. 227–253). Erlbaum.

Simonton, D. K. (2000). Creative development as acquired expertise: Theoretical issues and an empirical test. *Developmental Review, 20*, 283–318.

Sternberg, R. (1998). Abilities are forms of developing expertise. *Educational Researcher, 27*, 11–20.

Wallach, M. A., & Kogan, N. (1965). *Modes of thinking in young children: A study of the creativity–intelligence distinction.* Holt, Rinehart, and Winston.

Wallas, G. (1926). *The art of thought*. Harcourt Brace.

Zabelina, D. L., Colzato, L., Beeman, M., & Hommel, B. (2016). Dopamine and the creative mind: Individual differences in creativity are predicted by interactions between dopamine genesDAT and COMT. *PloS One, 11*(1), e0146768.