Estimating Creativity with a Multiple-Measurement Approach Within Scientific and Artistic Domains

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Abstract

This paper presents the structure and the composition of a newly developed multi-sided test battery for the measurement of creativity within scientific and artistic domains. By evolving and integrating some of the existing procedures for evaluating creativity, this test battery promises to become a full-rounded and comprehensive assessment of creative abilities, encompassing both domain-general and domain-specific components. More specifically, the test battery is designed for the measurement of the two main stages of the creative thinking process: ideation and assessment. The test battery also includes two measures of creative achievement, testing for Pro-C or Big-C Creativity. Both are tuned to represent measures of achievement in the artistic, scientific and everyday creativity domains. Moreover, since creative thinking is not an isolated phenomenon in human behavior, the battery includes the measurement of two constructs, intelligence and personality, both of which are highly relevant for creativity. Some preliminary results emerged from an administration campaign of this test battery are presented.

Keywords: multi-sided measurement of creativity; scientific creativity; artistic creativity

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The measurement of creative behavior is a difficult pursuit because creativity is a complex, multi-faceted construct that defies a single definition. The challenge is enhanced if we aim at addressing domains as different as those of artists/musicians and scientists/technologists, which we can expect to be characterized by diversified personal and methodological traits. Yet it is absolutely crucial to tackle this challenge if the objective is that of making a significant step towards understanding and finally enhancing creativity in these apparently disparate domains.

Indeed, the European Commission has launched a specific targeted research project (STREP) under the acronym CREAM (CReativity Enhancement through Advanced brain Mapping and stimulation), focused on the multidisciplinary study of the neural substrates of creativity in different knowledge domains. Using a multidisciplinary approach, this project joins 1) cognitive psychology, to provide a reliable, standardized measurements of creativity; 2) neuroscience, to reveal the neuronal network underlying creative cognition and its constituent stages; 3) information and communication technologies (ICT), to apply advanced signal processing techniques to monitor the creative cognitive states in real-time and to use brain stimulation instrumentation in order to establish a causal link between brain and body states with creative cognition.

In this paper we focus only on the first point, i.e. the integrated approach we have adopted to measure creative abilities and achievement, through the development of a specific multi-sided test battery. By uniquely combining and integrating some of the existing procedures for evaluating creativity, our approach promises to reveal a full-rounded and a comprehensive assessment of a person's creative abilities

encompassing both domain-general and domain-specific components. The main aim of this approach is indeed to measure the individual abilities associated to creativity in the artistic and the scientific domain, identifying the common principles regulating creativity within both domains and isolating the creative skills and tendencies primarily associated to each of the two knowledge domains. In the present paper, in particular, we present the structure and the measurement purposes of the test battery, explaining in detail the instruments composing this multi-sided measurement method. Moreover, in the concluding section a compendium of the preliminary results emerged form the administration of this test battery is provided.

Multi-sided test battery structure

In Figure 1, an overall view of the test battery structure is depicted. Since creativity is a multi-dimensional construct, different measurement methods have been included in the battery in order to quantify creative behaviour. Besides the measurement of ideational and assessment abilities, the battery includes two measures of creative achievement in scientific, artistic and everyday contexts. This measurement will allow individuating the main creative abilities associated to creative achievement in artistic and scientific domain. Finally, some methodologies aimed at measuring and controlling for the effect of constructs that are highly related to (i.e., influencing) creative behaviour, e.g., intelligence and personality, have been included in the battery. Following, a more detailed description of the methodologies included in the battery is presented.

- INSERT FIGURE 1 ABOUT HERE -

Creative behaviour measurement

The battery is centred on the measuring of two main states (stages) of the creative thinking process: ideation and assessment. Ideation in particular is measured

considering both the convergent and the divergent modality of the ideation process. While convergent thinking is usually defined as the thinking modality aimed at finding the right and unique solution, divergent thinking is defined as the thinking modality aimed at producing all possible alternatives. Both modalities are tested using methods of different nature: convergent thinking using tests of verbal, spatial and numerical nature, divergent thinking using tests of verbal, figural and realistic nature.

Even if the ideational phase of the creative thinking process is the most explored stage in creativity research, it is not sufficient to represent the complexity of the process by itself. The assessment of ideas for example has been demonstrated to be a completely separate ability in respect to the ideation ability (Runco & Charles, 1993). Therefore, a measurement of this ability has been included in the battery.

Convergent thinking

Remote Associates Test (RAT). RAT was developed by Mednick (1962) as a measure of creative thought that does not require specific knowledge of any field. Each question on the RAT is composed of three apparently unrelated cue words (triplet) that are associated to or associated from a fourth word, which is the correct answer. This test is typically used to study insight or insight-like phenomenon, as upon solving RAT items solvers often have the Aha! experience. Since remote associate problems have a single-word, unambiguous solution, RAT is used in the test battery as a task for testing the verbal convergent thinking ability.

RAT cue words are usually associated either through semantic association, synonymy, or formation of a compound word. However, triplets based on associations through synonymy or formation of a compound word are highly language dependent, i.e., their associations are related to the language of the three cue words. Differently, the associations based on semantic associations are not language-dependent, as the

semantic meaning is the same in the different languages. For this reason, in the test battery 18 different triplets have been chosen, which associations are of semantic nature. This choice will allow translating and using the battery in different languages. Triplets of different difficulties have been selected from past literature (the difficulty of a triplet is defined by the percentage of participants that accurately finds the associated word). Accordingly to the literature (see Bowden & Jung-Beeman, 2003) a time limit of 30 seconds is given to the participants to solve each problem.

Insight Problems. Insight problems may be seen as a special type of non-routine problems in which the problem primes an inappropriate solution procedure that is familiar to the problem solver. During an insight problem, the problem solver must overcome this familiar way of looking at the problem and invent a novel approach. Dow and Mayer (2004) in particular categorized the insight problems into verbal, mathematical, and spatial problems. In the battery a selection of 9 problems has been made, choosing 3 verbal, 3 mathematical, and 3 spatial problems. Participants have two minutes to find the solution to each problem.

Divergent thinking

Titles Task. Title task is used within the battery as a measure of participants' verbal divergent thinking and it is a divergent test widely used in the literature (Guilford, 1968). In particular, this task asks to produce some alternative titles for some widely known books or movies. In order to adapt the use of this task to the Italian culture, two books and one movie, which are very well known to Italian audience have been chosen. Differently from convergent tasks, divergent tests do not concern the identification of the right response, but they aim at stimulating the production of alternatives for some wide and ill-defined problems. To stimulate the production of alternative titles, participants are reassured on the fact that the task does

not concern any grades and that their ideas are confidential. In particular, they are asked to produce as many alternative titles as they can in three minutes for each title.

Figures Task. Figures task is used within the test battery as a task of figural divergent thinking. Differently from the verbal tasks, figural tasks are usually associated to higher originality scores, as verbal tasks are more constrained than the abstract figural tasks (Runco & Albert, 1985). In particular, in the test battery three abstract black and white line drawings are used and participants are asked to list all the things they can think of that each figure could represent. They are asked to produce as many ideas as they can in three minutes for each figure.

Realistic Problems. The third divergent thinking task is based on some realistic problems. Literature showed that realistic tasks have an advantage for fluency because they are more interesting, by virtue of their realism, or because the individual has more experience and, therefore, information (Runco, Dow, & Smith, 2006). In particular the problems included in the test battery have already been used in past researches (e.g., Runco, Illies, & Eisenman, 2005). The realistic task asks open-ended questions, but differently from the other two divergent tasks this task is focused on situations that participants (students) can actually experience. Participants are asked to produce as many alternative solutions as they can in three minutes for each problem (for a total of nine minutes).

Assessment of ideas

Judgement Task. Judgement task is a measure of participants' assessment ability. This task has been previously used in a series of researches to measure the assessment ability (Runco, 2013; Runco & Acar, 2012; Runco & Chand, 1994). The version used in the test battery represents a readaptation of the Judgement Task that is commonly used in literature. Participants are asked to judge the originality of 10 uses

of five different common objects on a 5 point scale (from 1 "Highly conventional /unoriginal", to 5 "Highly original"). In particular these uses derive from the uses produced in a previous study by 30 students of the same age range of the students involved in the administration campaign (Agnoli, Franchin, Rubaltelli, & Corazza, 2015). The 5 most original and the 5 least original uses produced in this previous study have been then chosen for each of the five common objects and included in the Judgement Task of the test battery. They are listed and presented to the participants in an alphabetical order. They have a total of 6 minutes to complete this task.

Creative achievement
Creative Achievement Questionnaire (CAQ)

Creative achievement is first assessed by the Creative Achievement Questionnaire (CAQ; Carson et al., 2005). This questionnaire measures creative accomplishments in 10 different domains. The CAQ aims to capture Pro-c or Big-C creativity (Silvia, Wigert, Reiter-Palmon, & Kaufman, 2012), and it focuses on significant, observable accomplishments. Carson et al. (2005) in particular demonstrated a two factors solution for the CAQ scores, explaining creative achievement in the scientific and artistic domain. A maximum of 10 minutes for the execution of this questionnaire is allowed to the participants.

Creative Activity and Accomplishment Check list (CAAC)

The Creative Activity and Accomplishment Check list (CAAC) is a self-report measure of creative achievement in different life domains. It was first used by Hocevar (1981) and than frequently used in creativity research (e.g., Milgram & Hong, 1999; Runco, Noble, & Luptak, 1990). The original version of the scale measures creative accomplishments in many domains. The version used in the test battery uses 45 items to measure creativity accomplishments in the artistic, scientific and everyday life domains. Each item represents an activity performed in one of these

three domains. This scale uses a four-point ordinal response scale. Participants, in particular, are asked to complete each item using the following scale: A = Never did this, B = Did this once or twice, C = 3–5 times, and D = More than 5 times. To take into account also the different levels of motivation in creative activities, each item asks how many times they performed an activity both within (low motivation) and outside (high motivation) the scholastic environment. With a time limit of 10 minutes, participants must respond to the list of activities and accomplishments in the various fields of study. They must circle the response (A-D) that best describes the frequency of the activity both inside and outside school (university), i.e., how often they have done each of the activities in school and outside school.

Constructs related to creative performance

Since creative thinking is not an isolated phenomenon into the human behavior, the battery includes the measure of two constructs that the literature demonstrated to be highly related to creativity: intelligence and personality. Even if psychological literature demonstrates that intelligence and creativity are distinct abilities (Kauman, 2008; Runco, 2007), intelligence has been demonstrating to be a central element in creative cognition (Nusbaum & Silvia, 2011). Moreover, the influence of personality on creativity is known (see for example Feist, 1999). For this reason, we considered within the test battery both general traits of personality and two specific traits strictly related to the creative performance, self-efficacy and motivation. Both these specific personality traits have been demonstrating to highly influence creative behaviour (Amabile et al., 1994; Bandura, 1984, 1986, 1997; Lubart, 1994; Prabhu et al., 2008).

Intelligence

Raven's Advanced Progressive Matrices (APM) short form. Raven's APM are one of the most used intelligence tests in Europe. They are widely employed to assess fluid ability in adolescents and adults (Raven & Raven, 2008). A limitation of

this test is its length: to shorten the administration time, we included in the test battery a short form of the test (APM- SF) developed by Arthur and Day (1994; Chiesi et al., 2012). This form is composed of 12 items of the APM – II Set (see APM Manual; Raven, Raven, & Court, 1998). Consistently with the long form, 3 items derived from Set I were used for practice before completing the APM – SF. After the completion of the practice items, participants have 20 minutes to complete the test.

Big-five dimensions

Ten Item Personality Inventory Scale (TIPI). The TIPI Scale is a methodology developed within a Big-Five theoretical framework. Among different rating instruments developed to measure the Big-Five dimensions, TIPI has been demonstrated to allow a rapid and valid assessment of the five factors (Goslin et al., 2003). In this 10-items inventory, each item of the scale represents one pole of the five dimensions. In particular, each item consists of two descriptors, separated by a comma. Each of the ten items is rated on a 7-point scale ranging from 1 (disagree strongly) to 7 (agree strongly). Participants are instructed to write one of the seven numbers next to each of the 10 couple of descriptors to indicate the extent to which they see themselves accordingly to this couple of adjectives. Participants are given 2 minutes to respond to the 10 items.

Self-efficacy

Self-Efficacy Scale. In the test battery self-efficacy is measured by the General Self-Efficacy Scale (Schwarzer, 1993). It is a ten-items scale that aims at measuring a broad and stable sense of personal competence to effectively deal with a variety of stressful situations. Participants are instructed to choose a number next to each of the 10 statements to indicate the extent to which the statement is true or not true for them.

They are instructed to use a four-point scale, from 1 "Not at all true" to 4 "Exactly true". Participants are given 2 minutes to respond to the 10 items.

Motivation

Work Preference Inventory (WPI). The Work Preference Inventory (WPI) was designed as a direct, explicit assessment of individual differences in the degree to which adults (college students) perceive themselves to be intrinsically and extrinsically motivated toward what they do (Amabile et al., 1994). Correlations between WPI scores and behavioral creativity measures showed that Intrinsic scores correlated positively with creativity, and Extrinsic scores correlated negatively with creativity (Amabile et al., 1994). Even if the original version of the WPI containing 30 items was written for working adults, it was readapted and some items were rewritten for college students. In particular the battery includes this last college student form. Participants are asked to respond on a 4-point scale how much each of the 30 items is true for them (from 1, "Never or almost never true of me", to 4, "Always or almost always true of me"). Four minutes are given to respond to this 30 items scale.

Conclusions

An administration campaign has been performed in the scientific and artistic communities of students at graduate level. In particular, more than 300 students from scientific and from artistic departments of the University of Bologna have been involved in the campaign. The measurement of creativity into these two knowledge domains aims at establishing a normative database to be used during the analysis of the brain substrates associated to creativity in Science and Art. Establishing the creativity characteristics in these two knowledge domains using reliable methodologies developed within the psychological research and using a

psychometrical approach to the analysis of the outcomes of the test battery are indeed prerequisites to guarantee a correct neuroscientific approach to the analysis of cerebral activity associated to creative behavior.

Some preliminary analyses have been performed on the data collected through this campaign. The first clear data trend emerged from correlational analyses highlighted a positive association between the two convergent abilities assessed within the test battery (i.e., the associative ability measured by RAT and insight measured by insight problems) and between these abilities and the cognitive abilities measured by the Raven intelligence test. Only insight was associated with creative achievement, and in particular with scientific creative achievement. On the other hand, divergent thinking abilities were highly associated with personality traits (Extraversion and Openness) and tendencies (intrinsic motivation) and with artistic creative achievement.

Further analyses are under way to the aim at defining the main predictors of creative achievement using CAAC data as reference scores for the analysis of creative achievement. Analyses performed in the scientific domain showed that personality traits and divergent abilities do not emerge as important predictors of scientific creative achievement. An exception is the positive predictive power of the fluency ability in the Titles task, which highlights the importance of thinking of many different alternatives when facing a problem in the scientific domain. All in all, self-efficacy emerged as the most important predictor of creative achievement in science. This personal tendency is related to the personal belief to be able to control a challenging environment by means of taking adaptive actions (Schwarzer et al., 1997). Moreover, self-efficacy interacted with the ability to solve problems by insight in the prediction of creative achievement. A moderation analysis in particular

highlighted that it positively predicted scientific creative achievement, and that it interacted with self-efficacy in the explanation of achievement. This effect, more specifically, showed that at low levels of the ability to solve problems through insight, believing in one's capabilities is extremely important in predicting the creative achievement, while at high levels of this ability, self-efficacy is no more an essential requirement. This result suggests that a complex interaction between convergent ability and individual tendency must be considered to understand and predict scientific creative achievement.

The analyses performed in the artistic domain show that personality and divergent abilities (i.e., both producing original responses and producing many alternatives) emerged as important predictors of artistic creative achievement. Different from the scientific domain, convergent abilities did not emerge as significant predictors. Also in the artistic domain, however, self-efficacy emerged as an important predictor of creative achievement. This tendency appears to be therefore a central individual disposition for achieving high creativity levels. Similarly to the results emerged in the scientific domain, the creative abilities (in particular the ability to produce original alternatives) interacted with personality in predicting the artistic creative achievement. An interaction effect between Openness and originality indeed showed the complex dynamics between these two variables in determining creative achievement. This effect shows that at low levels of Openness, the ability to produce original ideas is fundamental in achieving accomplishments in the artistic domain, but at medium and high levels of Openness, this ability progressively looses its importance in predicting creative success. Once again, these results demonstrated the importance of considering a complex blend of creative abilities and personality dispositions in measuring and predicting creative achievement.

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Further analyses must be performed in order to fully understand the main predictors of creative achievement in scientific and artistic domains. However, some useful suggestions can be drawn from these preliminary analyses. First of all, the complex interactive effects emerged between personality factors and convergent or divergent abilities show that creative achievement must be considered as a balanced blend of attitudinal and cognitive abilities, which measurement must necessarily consider both elements. Moreover, the estimation of creative achievement performed through this new multiple-measurement approach shows that performance in a single creative test cannot be considered sufficient to understand the creative achievement within a specific domain; on the contrary the measurement of a blend of specific variables emerging as predictors of creative achievement in a particular domain can be considered a valuable approach for the measurement and the analysis of this multifaceted construct in the neuroscientific research.

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Figure 1. Structure of the multi-sided measurement battery. The legend above the main figure indicates the inclusion of the measurement methods within three main categories: creative behaviour measures, creative achievement measures, and control variables measures.