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Cognitive dimensions of creativity: What makes the difference between creative and non-creative university students?

This paper analyses the contribution of specific cognitive functions on creative performance. The main question was which cognitive variables differentiate extreme levels of creative performance and therefore can characterize highly creative college students. A sample of Portuguese university students of Fine Arts and Literature (n=166) took part in this study. A battery of verbal and figural cognitive tasks, as well as two kinds of creative tasks (text and poster production) have been considered. Results showed that there were mostly the same cognitive dimensions (figurative reasoning, divergent thinking, insight problem solving, and problem-finding), which differentiate extreme levels of creative performance in both text and poster productions. These results are discussed considering the relevance of the cognitive approach to explain creativity. Some practical ideas, possible to put into the educational context, are also discussed.

Keywords: *Creativity, Divergent thinking, Creative production, Cognitive functions*

Introduction

As Feldman (1988) mentioned, creative expression is a rare phenomenon resulting from demanding co-incidence. Creativity requires several factors to act at the same time, both in the individual who creates and in his or her surrounding environment. Therefore, creativity corresponds to the manifestation of a complex interaction of factors, and such complexity causes difficulties in efforts to understand this phenomenon while taking any partial approach (Lubart & Guignard, 2004; Simonton, 2004). However, there is still a great deal of exploration to be done regarding various aspects of creativity and the way they can be combined in some compound form (Csikszentmihalyi, 1999; Sternberg & Lubart, 1995, 1996). One way to overcome the limits of studies on creativity is to use a wide range of methods and evaluation instruments (El-Murad & West, 2004). Yet assessment of creativity is regarded to be an extremely difficult and vehement topic, particularly if psychometric instruments are used (Baer, 1994; Kaufman & Sternberg, 2006).

In order to overcome such difficulties, some authors suggest assessing creativity through creative products. This form of assessment provides greater ecological validity and allows increasing the reliability of measurement, which may be quite low in the case of simpler measures of creative potential (Amabile, 1996; Baer, Kaufman, & Gentile, 2004; Runco & Charles, 1997). Such an approach is also adopted in this study.

According to the well-known 4P approach (Rhodes, 1961; Richards, 1999; Runco, 2004), the phenomenon of creativity can be analyzed from four perspectives, which pertain to Creative Process, Creative Person, Creative Product, or Social Press. In this paper, we focus on the cognitive dimension of creativity. It means that we understand creativity as a particular form of problem solving, and aim at identification of cognitive processes that are able to mediate between the characteristics of a person and his or her productions (Lubart & Mouchiroud, 2003). Searching for creative cognitive functions (cf. Finke, Ward & Smith, 1992) seems to be a useful way of conceptualizing creativity as a process rather than a personal trait. Specifically, we wish to identify a combination of

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cognitive variables that can maximize the differentiation among young adults with high and low levels of creative performance. So, we start with a convergent thinking test (analogies), in order to address the classic controversy about IQ and creativity relationship. Several authors conclude that general intelligence, assessed with convergent thinking tasks, is necessary although insufficient to explain creative potential (Kaufman & Baer, 2002; Sternberg & Lubart, 1995). For example, inductive-deductive reasoning skills seem to be important for creative processes, particularly in the domain of scientific creativity and problem solving (Dunbar, 1995; Isaak & Just, 1995). Analogical thinking facilitates the formulation of hypotheses (Clement, 1989), creation of alternatives (Isaak & Just, 1995), understanding of new issues as something familiar (Eysenck & Keane, 1990), and, consequently, improving insightful problem solving (Dunbar, 1995). Also, mental manipulation with figural contents, or imagery, has been closely associated with creativity because it facilitates the cognitive representation of a problem, faster or more flexible processing of information, which can be important for quick production of original associations leading to creative answers (Finke, 1997; LeBoutillier & Marks, 2003).

Another important cognitive dimension of creativity is the divergent production of ideas, usually assumed to be more important to creative performance than general intelligence (Guilford, 1967; Runco, 1992, 2003). It is a kind of thinking that aims at plurality of answers, both in quantitative terms (fluency) and at the qualitative level (flexibility, originality and elaboration). But before any problem is solved, it must be identified and formulated. So, problem finding is another dimension frequently associated with creativity (Runco, 1994). We look at problem-finding as a set of cognitive skills such as making up themes, formulating and forecasting problems, asking questions, being sensitive to paradoxes, mistakes or lapses, or deducing a problem on the basis of its solution (Dillon, 1992; Getzels, 1987; Jay & Perkins, 1997). Both the divergent production ability (in its verbal and figurative aspect) and problem finding skills are measured in this study.

We also decided to explore the significance of insightful problem solving. It is the ability to find a solution on the basis of a sudden change in perceptive or cognitive representation of a problem situation. Insight usually means sudden restructuring of information, specifically sudden restructuring of the cognitive representation of a problem at hand (Davidson, 1995; Segal, 2004). Several models (Jones, 2003; Langley & Jones, 1988; Seifert et al., 1995) explain this phenomenon of restructuring with peculiarities of information processing, and underscore the role of analogical thought or simultaneous combination of remote pieces of information. In this study, insightful problem solving will be taken into account as a cognitive process possibly accounting for individual differences in the levels of creative productions.

The main objective of this study is to find out which cognitive functions are more or less important for verbal and figurative creative productions. Another objective is to explore which of these cognitive functions differentiate more and less creative individuals. Looking for answers to these questions, we pay attention to the importance of domain-specific knowledge (Amabile, 1996; Mednick, 1962; Simonton, 2000). Thus, we decided to investigate two different samples consisting of university students from two domains. In such a way, we should be able to find out whether domain-specific knowledge enters into any interaction with the formerly mentioned cognitive dimensions as a predictor of creative performance.

Method

Participants

The sample consisted of 166 volunteer university students, 84 from the Literature and 82 from the Fine Arts departments. There were 128 women and 38 men in this sample, this proportion by and large represents gender disparity in the whole population of the Literature and Fine Arts students. Participants were recruited in the two public universities of northern Portugal (Porto and Minho).

Instruments

Insightful problem solving. An instrument that we used is called the Insightful Problem Solving. It was devised by Morais (2001) and consists of 10 verbal tasks ordered by their level of difficulty. Each task corresponds to a specific insight problem, i.e., a problem that requires restructuring of its cognitive representation. The representation initially induced by the situation must be changed in order to achieve the solution*[1]. The duration of the test is 45 minutes. The final score corresponds to the number of problems correctly answered. Concerning internal consistency measures, the Kuder Richardson (KR20) coefficient was 0.72. A confirmatory factor analysis supported a solution with one general factor which explains the majority of variance.

Problem finding. This test, introduced by Morais (2001), consists of four verbal items. Considering one real and one fictitious situation, two items require putting questions (questions to a drop of sea water and questions to a man who began to see only when he was 20 years old) and two others require formulation of forecasting problems (what would happen if men could be pregnant and what kind of problems car drivers will have to cope with in the

1 Example of a problem situation: Two men play five checker games and each wins an even number of games, with no ties. How is that possible? (Source: Sternberg & Davidson, 1982). Initial representation: try to determine combinations of games; insightful representation: the men didn´t play against each other.

Table 1
Descriptive statistics on variables by both groups and global sample.

Variables	Global sample (n=166)			Fine Arts (n=82)			Humanities (n=84)		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Insight	4.7	2.16	0-8	5.2	2.01	1-8	4.1	2.18	0-8
Problem-finding	28.8	8.03	10-55	27.4	7.96	10-47	30.0	7.94	15-55
Figural reasoning	10.0	3.58	1-18	11.3	3.03	4-18	8.7	3.60	1-17
Verbal reasoning	12.5	3.58	3-24	12.4	4.39	3-24	12.5	3.49	6-22
Figural divergent thinking	9.7	4.88	1-26	12.4	4.81	2-26	7.2	3.35	1-17
Verbal divergent thinking	11.8	5.04	0-25	12.1	5.29	2-25	11.5	4.81	0-25
Texts	3.0	0.75	2-5	3.2	0.81	2-5	2.8	0.66	2-5
Posters	3.0	0.80	2-5	3.5	0.72	2-5	2.5	0.41	2-4

next 20 years). There is a time limit of five minutes for each item. The scoring is based on fluency (quantity of different answers), and the final score is the total sum of questions and forecasts. Differences between contents (fictitious and real) and between problem finding skills (putting questions and forecasting problems) appeared statistically significant ($t=4.42$, $df=155$, $p<.05$, in the first case; $t=21,6$, $df=155$, $p<.05$, in the second one). Concerning internal consistency of items, Cronbach's alpha coefficient was .75 and the judges' agreement rate was .96. A confirmatory factorial analysis showed a unifactorial model as adjusted to explain the results on four items.

Figurative and verbal reasoning. This is a test of convergent problem solving skills, specifically deductive and inductive reasoning, devised by Ribeiro and Almeida (1993). Both figurative and verbal subtests comprise 25 items, ordered by their difficulty level. Each item corresponds to an analogy (between abstract designs and between words) and the participant is supposed to choose an answer from among five alternatives. The figurative test lasts 10 minutes and the verbal one lasts 5 minutes. The final score of each subtest is the number of items/analogies correctly answered.

Concerning internal consistency of items, the Kuder Richardson (KR20) coefficient was .82 and .83 in respect to verbal and figurative tests.

Figurative and verbal divergent thinking. This instrument, introduced by Ribeiro and Almeida (1993), consists of two figurative and two verbal items. A participant has three minutes for each item. In the figurative subtest, a participant should create figures from given figurative elements, and at the end of each production he or she should give a title and identify the elements used. In the verbal subtest, a participant should write sentences using four words given in a specific order. These sentences should be meaningful. The score of each answer varies between 0 and 3 points depending on its quality. Answers which repeat parts of a previous task are not taken into account. This scoring system includes criteria of quantity (the number of pertinent answers), diversity (similar answers are excluded), and originality (higher values are given to less frequent productions). The judges' agreement rates were .94 and .93 in respect to verbal and figurative tests.

Creative products. Participants were invited to produce a text and a poster. As to the texts, they were requested to write an essay that could be read at a scientific conference about "Animals in captivity and the future". It should have been in prose and not surpass one sheet of paper. The duration of this task was 40 minutes. As to the production of posters, the theme was "Environmental pollution and the future". The posters should be made in pencil on one sheet of paper. Students were requested to prepare their posters for a fictitious scientific conference on environmental pollution. The duration of the task was 35 minutes. Both productions were assessed on a scale of 9 levels (from 1 to 5 with intervals of 5 points) independently by three experts (Portuguese Language and Art teachers for the texts and the posters, respectively). The criterion for this assessment was the subjective perception of creativity of the product (Amabile, 1983). The judges' agreement rates were .76 and .74 in respect to texts and posters.

Procedure

First, the main objectives of the study were explained to the participants. Then, confidentiality of their results was assured. They were also promised to obtain feedback in writing. Test administration occurred during classes with teachers´ permission. The instruments were administered in the following order: text production and insight problems (first session), poster production, problem-finding, figurative and verbal reasoning, figurative and verbal divergent thinking (second session)

Results

Table 1 presents means, standard deviations, minima and maxima of all variables that were measured in this study. These data are also split into two subgroups. Several differences between both groups appeared statistically

Table 2
Structural canonical coefficients for Posters and Texts.

	Posters	Texts
Figurative reasoning	.544	.581
Figurative divergent thinking	.530	.538
Insight	.440	.448
Verbal reasoning	-.337	.033
Problem finding	.308	.297
Verbal divergent thinking	.077	-.033

significant (see bold and italic values on table). Fine Arts students scored better on Insight ($t=2.24$; $df=161$; $p<.05$), Figural reasoning ($t=4.83$; $df=144$; $p<.05$), Figural divergent thinking ($t=7.55$; $df=144$; $p<.05$), Posters ($t=10.62$; $df=147$; $p<.05$) and Texts ($t=3.26$; $df=153$; $p<.05$). Humanities students obtained higher scores on Problem-finding ($t=2.10$; $df=154$; $p<.05$). No difference was found on Verbal reasoning. These results suggest generally better performance on cognitive tests and creative productions by Fine Arts students, although these differences are less salient concerning verbal scales.

Discriminant analysis was carried out in order to identify combinations of cognitive variables that maximize the distinction between extreme levels of creative performance. In taking such an approach, we aimed at understanding what characterizes high performance on the different creative tasks, that is, Texts and Posters. Discriminant groups (i.e., individuals assessed as non-creative and very creative) were analyzed in reference to both tasks. The statistical coefficients inherent to the discriminant analysis, as well as the respective levels of significance, the structural canonical coefficients of each variable, and the percent of cases correctly classified in both groups, were calculated. Considering the scores on Posters, the values obtained were: Wilkes's Lambda =.811; Canonical correlation (Rc) =.434; Chi-square (6) =15.681; p=.016. The percentage of subjects correctly classified was 69%. Considering the scores on Texts production, the statistics were as follows: Wilkes's Lambda =.853; Canonical correlation (Rc) =.383; Chi-square (6) =13.466; p=0.36. The percentage of individuals correctly classified was 66%. The structural canonical coefficients for both tasks of creative productions are presented in Table 2.

Taking into account both kinds of creative performance, we can identify cognitive variables that differentiate extreme groups of creative performers. Considering that coefficients at the level of .30 or higher should be taken for such differentiation (Huberty & Morris, 1989), we can observe that the only difference between the two types of creative accomplishment refers to the negative value contribution of verbal reasoning to poster productions. It seems quite clear that both creative tasks need very similar cognitive processes to be accomplished at a high level of performance. In other words, similarities rather than differences have been observed concerning the cognitive prerequisites needed for accomplishment of two types of creative tasks. We can see that, in both cases, the main variables are Figurative reasoning, Figurative divergent thinking and Insight problem solving. Problem finding has an acceptable limit value, too. Verbal divergent thinking does not contribute to differentiation between extreme groups of creative performers. In the discriminations obtained, there is an apparent error of about 30%. However, such a result must be expected by the fact that creative performance was predicted only by a few cognitive factors. Knowing that creativity is a broad and multifaceted concept, it seems to be an acceptable result to assure 70% of correct replacements.

Discussion and Conclusions

The results of this study suggest that there are a number of cognitive variables that matter as predictors of creative performance: reasoning ability, divergent thinking ability, insight problem solving ability, and problem finding ability. Since the reasoning ability is close to traditionally defined intelligence, we have to conclude that a high level of creative performance needs first of all general intelligence, which must be balanced by purely creative skills, such as divergent thinking, insight problem solving, and problem finding. However, only the figurative versions of reasoning and divergent thinking tests appeared important as instruments that allowed discrimination between high and low levels of creative performance. Verbal versions of theses tests did not contribute at all, or —in the case of verbal reasoning — brought about the opposite pattern of relationships. Since we did not apply nonverbal versions of insight and problem finding tests, we cannot decide whether this pattern of relationship reflects some general rule, according to which only figurative measurement instruments are able to provide valid discriminations between various levels of creative performance. Finally, we have to underscore that the instruments we used did not allow us to identify any differences between two separate types of creative productions. Both Posters and Texts obtained a rather similar coefficient (see Table 2), which means that cognitive requirements of a creative work are quite similar regardless of the type of tasks. How can such findings be explained?

First, let us point out that levels of intelligence slightly above the average (IQ between 110 and 120) is viewed as one of the necessary conditions of creativity; therefore, weak creative performance is generally associated with low levels of intelligence (Walberg, 1988). However, intelligence usually appears as a necessary but not sufficient condition of creativity (Kaufman & Baer, 2002; Sternberg & Lubart, 1995). Our results suggest that creative performance needs both convergent and divergent thinking skills. Many authors (e.g., Kaufman & Baer, 2004) emphasize the combination of both types of skills, or two types of cognitive styles, in creativity. It seems that, in this study, the difference between excellent and poor creative performance may be related to differences in one's ability to manage the process of production of alternative ideas, in one's logical and critical selection of goals, and in one's evaluation skills. All these skills are covered by the notion of general intelligence. So, it seems entirely explicable why the figurative reasoning test appeared so important in this study. The only problem refers to the question of why it appeared to be the most important factor differentiating students who showed high and low creative performance. We believe that this question must be open for further research.

Now, let us discuss the question of why only the figurative versions of our measurement instruments appeared good discriminators between more and less creative students. It seems reasonable to point out that figurative reasoning tests imply not only the ability to think in abstraction but also, to some extent, the imagery skills (Finke, 1997; LeBoutillier & Marks, 2003). In other words, the instrument we applied probably covered more than one domain of cognitive performance. For instance, the figurative reasoning test measured not only general intelligence but also imagery. The figurative test of divergent production measured not only the production of a variety of ideas but also imagery. And it is quite well-established that the figurative channel of information processing is relevant to creative thinking. The quantity and diversity of information allowed for processing through the imagery system (e.g., flexibility of focusing on global or local aspects of information) increase the probability of remote associations that are vital for creative behavior (Mednick, 1962). Maybe, if only the verbal versions were applied, they would appear important predictors of creative performance because of their involvement in reasoning and divergent production. However, these verbal versions probably lost their predictive power while being accompanied by figurative versions which, apart from their involvement in reasoning and divergent production, were also associated with the domains of imagery and figurative thinking.

The significance of imagery for creative productions can also be illustrated by the fact that the verbal reasoning test showed its negative value in the case of posters production, meaning that authors of creative posters obtained low scores in this test, and vice-versa. Apparently, we have to agree with Runco and Albert (1991) that verbal processing of information results in lower level of novelty in one's intellectual productions. Moreover, the verbal reasoning test probably required some amount of linguistic knowledge, particularly in the case of items that were based on such relations as similarity or opposition between concepts. If so, the vocabulary span could be important in this instrument, and the negative role of verbal reasoning in the creation of posters appears quite explicable.

Insight and problem finding skills appeared less important, although they were identified as necessary for the distinction between participants who produced more and less creative outputs. In our opinion, such contribution cannot be perceived separately from other variables. Insightful problem solving appeals to multiple characteristics of cognitive processing (Langley & Jones, 1988; Seifert et al, 1995), which are not independent of intelligence (Davidson, 1995),divergent production (Smilansky & Halberstadt, 1986) or imagery (Blakeslee, 1980). The instruments that were adopted in this study were selected on the basis of dominant type of cognitive processing; however, they were not pure enough to exclude other types of processing. Contamination of cognitive tests with influences from the skills and processes that were not supposed to be measured seems inevitable. Even the most popular tests of cognitive performance, such as Raven's Progressive Matrices (Raven, Court & Raven, 1983) are not pure measures of general intelligence because apparently they are subjected to contamination with other skills, e.g., spatial orientation (cf. Hunt, 1974).

Now, we can reflect why both sets of differentiating variables, as well as the magnitude of their respective structural canonical coefficients, appeared quite similar in the case of figural and verbal creative productions. We expect rather opposite patterns of results because research on creativity demonstrates the relevance of domain specificity: correlations coefficient between quality of creative products coming form different domains are usually not so high (Baer, 1993; Sternberg & Lubart, 1995). On the other hand, there seem to exist some nuclear, or elementary, cognitive skills, e.g., remote associations of ideas (Gruszka & Necka, 2002; Martindale, 1999; Mednick, 1962) that are necessary for every creative activity and therefore occur across different domains. Our results clearly suggest that generality rather than domain specificity should be regarded as a rule of creativity. However, one must realize that the criteria used to assess creative productions did not include any academic knowledge because only the general idea was taken into account. This fact certainly has contributed to a finding that quite similar sets of variables appeared significant, regardless of the domain involved. Future research should therefore include creative tasks that would be rather unfamiliar to different groups of participants. In this way, the role of transfer in creative problem solving may be analyzed, as well as the question of domain specificity concerning creative thought.

In any case, this effect of similarity concerning two groups of participants can also be interpreted in terms of relevance, or irrelevance, of academic background for the quality of creative productions. We found that there were very good and very weak creators among both Fine Arts and Humanities subgroups, although the nature of at least one task should put the Fine Arts students in the privileged position. Does it mean that our university courses do not cover skills that are important for creative imagination, even if some of them should apparently lead to increased levels of creative skills? It may well be that Fine Arts students are taught techniques of drawing or painting but not creativity. We believe that creativity can be, and should be, taught through university courses, although this problem probably could not win enough attention from the persons and institutions that are responsible for curricula development.

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