Creativity Research Journal
2004, Vol. 16, No. 4, 415–420

The Creativity Quotient: An Objective Scoring of Ideational Fluency

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ABSTRACT: A classical test for accessing the potential creativity of an individual is based on ideational fluency, where a person is asked to generate all possible uses for a familiar item like a piece of paper. In scoring the results, it is intuitive that the suggested uses should not be weighted equally. Those suggested in radically different categories are "worth more" than those suggested within the same category only. We used information theory to derive a simple mathematical expression for a more objective measure of ideational fluency. We call this the creativity quotient (CQ). This innovative measure was examined using a small sample of participants, and is illustrated by the responses of two typical individuals from an ideational fluency task. The CQ accounts for the number of ideas (fluency), plus the number of categories (flexibility). Ongoing research will examine the independence of CQ from established measures of intelligence and personality.

Ultimately the only proven test for creativity is the creation itself, although there have been many suggested indicators. One indicator is provided by ideational fluency. Here a person is asked to suggest all possible uses for a familiar item, such as a piece of paper. A number of authors have considered this since its origins in 1924 (Bryan & Luszcz, 2000; Carroll, 1993; Cattell, 1943; French, Ekstrom, & Price, 1963; Getzels & Jackson, 1962; Guilford, 1959; Hocevar, 1979; Kaufman, 1981; Obonsawin et al., 2002; Runco & Mraz, 1992; Thurstone, 1924; Turner, 1999; Ward, 1969).

A long-standing problem with ideational fluency is how to determine an objective evaluation of the responses (Getzels & Jackson, 1962; Guilford, 1959; Hocevar, 1979; Kaufman, 1981; Obonsawin et al., 2002; Runco & Mraz, 1992; Ward, 1969). As Guilford (1959) and others (e.g., Getzels & Jackson, 1962) noted, the development of scoring procedures for tests of creativity presents unusual problems. It is intuitive that the suggested uses should not be weighted equally, as is often done (e.g., Bryan & Luszcz, 2000; Obonsawin et al., 2002). In particular, those uses offered in distinctly different categories should be weighted more than those that fall in the same category (Getzels & Jackson, 1962; Guilford, 1959).

For example, after first suggesting writing, the three suggested additional uses scribbling, printing, and drawing should intuitively be weighted less than the three: make a funnel, cut paper dolls, use as insulation. The first three fall in the same category of surface marking whereas the second three fall into three distinctly different categories. A fundamental approach is needed that places these observations on a more solid theoretical ground.

This research was supported by an Australian Research Council Discovery grant. We thank Maria Hennessy, Jane Rouse, and Angela Yates for their insights on this research.

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We use information theory (Shannon & Weaver, 1949) to derive a more objective measure for ideational fluency. This leads to a "creativity" quotient CQ which accounts for the number of ideas (fluency) and the number of distinct categories the ideas fall into (flexibility). CQ can be represented in a number of equivalent ways, the most easily interpreted is given approximately as

$$CQ \cong N_c + 1/2\, n_2 + 1/3\, n_3 + 1/4\, n_4 \ldots \quad (1)$$

where N_c is the number of distinctly different categories suggested for a familiar item, say a piece of paper; n_2 is the number of distinctly different categories for which at least two suggested uses were given; n_3 is the number of different categories for which at least three suggested uses were given and so on (see Appendix A for an expanded explication).

In other words, the first answer offered in a particular category increases the creativity quotient (CQ) by 1, whereas the second answer offered in that same category increases CQ by only 1/2, the third by 1/3, the fourth by 1/4 and so on.

For example, seven uses advanced in a single category is shown from eq(1) to have a CQ of only $\cong 3$. This is because N_c and n_2 through to n_7 have a value of 1 with all other ns equal to zero.

Seven uses, each in a different category results in CQ =7. This is because $N_c = 7$, with all the ns equal to zero in Equation 1.

Method

Participants

Participants ($N = 25$) were presented with a measure based on Guilford and Christensen's(1956; see also Carroll, 1993) construct of Ideational Fluency (see, French, Ekstrom, & Price, 1963, for a full description of the task structure).

Task Description and Testing Procedure

To ensure that the task was relatively independent of learning, an item that could be assumed to be familiar to all was selected, in this case a piece of paper. The task requirement followed the procedure of French et al. (1963) and requested participants to list as many uses for the piece of paper as possible within a 5-min period. This period was determined from a previous study where, after 5 min, most people appeared to have run out of new ideas. At the end of the test session volunteers were debriefed on the nature of the experiment and thanked for participating.

Mathematical Procedure

Heuristic derivation of CQ. We here provide a heuristic derivation of the CQ. The derivation is conceptually similar to that used to determine the information capacity of vertebrate and invertebrate eyes (Snyder, Bossamaier, & Hughes, 1986; Snyder, Laughlin, & Stavanga, 1977).

To do this we were motivated by an appealing definition of creativity: the ability to link seemingly disparate ideas into a novel synthesis. The potential to achieve such a novel synthesis is increased by having a reservoir of distinctly different ideas about something plus a number of subtle ways to express each of these ideas.

From this reasoning, an objective measure of potential creativity is the number of possible combinations of uses for a familiar item. To see what we mean by the number of possible combinations, consider the example of uses of a piece of paper. Suppose that there are only three distinct categories suggested, say surface marking, utensils, and toys.

Now the number of possible combinations for uses of paper found by taking uses from each category leads to $(1 + u_1)(1 + u_2)(1 + u_3)$, where u_1, u_2, u_3 are respectively the number of uses offered in each of the three categories respectively. When no answer is given in Category I, then $u_i = 0$.

Generalizing to the situation when the number of categories N_c is arbitrary, then the number of possible combinations of uses for a piece of paper are given by $(1 + u_1)(1 + u_2)(1 + u_3) \ldots (1 + u_c)$, where u_c is the number of uses offered in Category c.

Now, because the number of combinations is usually large and because the information of each category should be additive, it is traditional in information theory to take the logarithm base 2 of the number of combinations. This leads to the information capacity of a person's responses, or what we call the CQ, where

$$CQ = \log_2 \{(1 + u_1)(1 + u_2) \ldots (1 + u_c)\} \quad (2)$$

We are reminded that u_1, u_2, u_3, u_c are respectively the number of uses offered in categories 1, 2, 3, and c. This expression for CQ has a simple interpretation. For example, if all suggested uses fall into one category, say category 1, then only u_1 is nonzero, so $CQ = \log_2 (1 + u_1)$. If they each fall into one of N_c distinctly different categories, then all the us in Equation 2 are equal to 1 and $CQ = \log_2 (2^{N_c}) = N_c$.

Therefore, if there are 15 different uses suggested, but all in one category, then $CQ = \log_2 (16) = 4$. If, at the other extreme, they are each in a different category, then CQ = 15. Thus, subtle variations of uses within the same theme are weighted less than those that fall into distinctly different themes.

Because log base two is not often available, it is convenient to convert to the natural logarithm. Recall that log to any base x is related to $\log_2$ by the relation

$$\log_2 A = \log_x A/\log_x 2 = 1.44 \ln A \qquad (3)$$

where ln is the natural logarithm.

Alternative expression for CQ. Equation 2 is the most convenient for calculating CQ scores, but it is not the best for imparting an intuitive understanding. To do this, we rewrite Equation 2 as

$$CQ = N_c + n_2 \log_2 3/2 + n_3 \log_2 4/3, \ldots + n_j \log_2 (1 + j)/j \qquad (4)$$

where N_c is the number of distinctly different categories suggested for a familiar item, say a piece of paper, n_2 is the number of distinctly different categories for which at least two suggested uses were given, n_3 is the number of different categories for which at least three suggested uses were given and so on. This leads from Equation 3 to

$$H \cong N_c + .58\, n_2 + .41\, n_3 + .32\, n_4 + .26\, n_5 + .22\, n_6 + .19\, n_7 \ldots + 1.44 n_j \ln (1 + j)j \qquad (5)$$

We can use the approximation, $1.44 \ln(1 + j)/j \sim 1.44/j$, which is less than 6% in error for $j > 7$, becoming more accurate for larger values of j. Equation 1 provides a useful approximation of Equation 5.

This last expression, or equivalently Equation 1, imparts an intuitive understanding of the CQ given by Equation 2. For example, it clearly shows that the first answer offered in a particular category increases the CQ by 1, whereas the second answer offered in that same category increases CQ by only .58, the third by .41, the fourth .32, and so on.

Designating the categories. To calculate the score CQ for ideational fluency, it is necessary to first partition all the responses into different categories. This is itself a subject of intense theoretical interest (Cattell, 1943; Rosch, 1988; Thurstone, 1924). In fact, the use of so-called 'Roscherian' categories provides a very convenient way of distinguishing between the various ideas generated by individuals.

The absolute magnitude of the score CQ will be directly dependent on the number of categories chosen. For example, the more narrow or finely grained the categories, the greater the potential absolute CQ score, and the more nearly the CQ score approaches the total number of ideas (fluency). This is because there is one idea per category. On the other hand, with too few categories, flexibility is devalued and the CQ score is low. However, a judicious choice of categories leads to a meaningful normalization for CQ. Accordingly, the maximum score CQ is normalized to a particular predetermined set of categories in this first step towards defining a metric for ideational fluency.

Results

Examples: Uses of a Piece of Paper

We asked a number of participants to suggest all possible uses for a piece of paper. The results for two of these participants are provided next to demonstrate the application of the previous formalism.

Participant JKL: In Figure B1 (see Appendix B) we list the 23 uses suggested for a piece of paper offered by participant JKL after 5 min of testing. These have been partitioned into the seven categories "surface marking," "toys/games," "utensils," "clothes," "wrapping," and "unusual" one and two. The number of suggestions in each of the seven categories specifies u_1, through u_7 as shown in Figure B1.

Using Equation 2, we find that

$$CQ = \log_2(6 \times 5 \times 5 \times 5 \times 5 \times 2 \times 2) \qquad (6a)$$

$$= 1.44 \ln 15{,}000 \cong 14 \qquad (6b)$$

Participant HM: In Figure B2 (Appendix B) we list the 19 uses of paper suggested by participant HM, apportioned as above but in this case into two categories only. Using Equation 2,

$$CQ = \log_2(18 \times 3) \quad (7a)$$

$$= 1.44 \ln 54 \cong 6 \quad (7b)$$

Although participant JKL provided only four more responses than did participant HM (23 vs. 19), nonetheless, his CQ was more than double (14 vs. 6).

Discussion

Ideation theory in its broader sense describes how fluency, flexibility, and originality of ideas are each important for creative thinking (Runco & Chand, 1994). The CQ accounts for the trade-off between fluency (number of ideas) and flexibility (number of categories the ideas fall into). It is embedded in the notion that there is more creativity involved in going on to suggest new categories, rather than to suggest additional uses within the categories that have already been mentioned. For example, if a person has suggested writing, printing, and drawing as uses of paper, then the additional suggestion of making hats increases CQ more than would have painting. This seems reasonable, because a hat requires the concept of folding paper into an item of clothing, whereas painting is just an additional example of surface marking.

The CQ estimates the potential for creative thought. In particular, CQ could apply directly to the notion of creativity as an ability to link very different ideas into a novel synthesis. This is because the potential to make such links presumably increases with the number of distinctly different categories of ideas a person has about something plus the number of ideas they have to richly express each category.

It would be interesting to examine whether or not those with the highest CQ scores are indeed the ones who best realize this theoretical potential of creating new ideas by joining ideas from distinctly different categories. As an example, to generate the new idea of using paper for aerial advertising, by combining the idea of using paper for a balloon with the idea of printing on paper. How will the ideas arising from such combinations score for originality?

In future research we seek to assess the extent to which CQ scores are related to scores on more standard measures of cognitive abilities and personality. This validation procedure is intended to establish the CQ's independence from traditional IQ-type scores, as well as examining possible relations between intelligence, personality, and creativity. In addition, we will investigate how participants themselves categorise ideas, comparing this with Roscherian categorizations.

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Appendix A
Information Theory Derivation of the Creativity Quotient

The information capacity H for a number, N_c, of discrete independent channels is approximated by (e.g., Shannon & Weaver, 1949; Wozencraft & Jacobs, 1967)

$$H = \sum_{I=I}^{N_c} \log_2 (1 + u_i) \qquad \text{(A1)}$$

where u_i is the signal to noise ratio or equivalently the number of discernable states for the Ith channel.

In the context of ideational fluency, the discrete channels are the distinctly different categories of suggested uses for, say paper, while the states within each channel are the suggested uses within each category. In other words, Equation 2 and Equation A1 are equivalent.

Information Increase per Additional Category

It is convenient to determine the increase in the information within one category only, that is, as u_i increases from zero to one, from one to two, and so on. With each additional suggested use j, the information of Category I increases by an amount DH_i given by

$$\Delta H_i = \log_2 (1 + j) - \log_2 (1 + j - 1) \qquad \text{(A2a)}$$

$$= \log_2 (1 + j)/j \qquad \text{(A2b)}$$

This tells us that the first suggestion ($j = 1$) in category I leads to an information $\log_2 (2) = 1$, whereas the second suggestion ($j = 2$) in the same category increase the information by an amount $\log_2 (3/2)$.

Alternate Expressions for the Total Information

We can use Equation A2 to express the total information content of Equation A1 by the alternative form,

$$H = \sum_{j=1}^{N_c} n_j \log_2 (1 + j)/j \qquad \text{(A3)}$$

where the summation is over the number categories that have j suggestions and n_j is the number of categories with j suggestions ($n_1 = N_c$). Writing this in a more explicit form,

$$H = N_c + n_2 \log_2 3/2 + n_3 \log_2 4/3 \ldots + n_j \log_2 (1 + j)/j \qquad \text{(A4)}$$

where N_c is the total number of categories suggested, n_2 is the number of categories with two or more suggested uses and so on with n_j is the number of categories with j suggested uses.

Converting from base 2 to the natural logarithm, leads from Equations 3 and A4 to

$$H \cong N_c + .58n_2 + .41n_3 + .32n_4 + .26n_5 + .22n_6 + .19n_7 \ldots + 1.44n_j \ln(1 + j)j \qquad \text{(A5)}$$

This is approximated by Equation 1. We can use the additional approximation

$$\ln(1 + j)/j \sim 1/j \qquad \text{(A6)}$$

which is less than 6% in error for $j > 7$.

Appendix B

Surface Marking	Toys/games	Utensils	Clothes	Wrapping	Unusual 1	Unusual 2
Writing	Airplane	Straw	Hat	Wrapping paper	Look at sun through hole	Make noise
Scribbling	Ball	Funnel	Eye patch	Envelope		
Printing	Kite	Sieve	Arm band	Cigarette paper		
Painting	Origami	Cleaning windows	Sweat band	Lolly wrapper		
drawing						
$u_1 = 5$	$u_2 = 4$	$u_3 = 4$	$u_4 = 4$	$u_5 = 4$	$u_6 = 1$	$u_7 = 1$

Figure B1. *Participant JKL responses for uses of paper where the us are the number of suggested uses within each category required to calculate creativity quotient in Equation 2.*

Surface Markings	Wrapping
Writing	Cover box
Printing	Wrap food
Painting	
Letter	
Love poem	
Birthday card	
Newspaper	
Poster	
Ticket	
Picture	
Book	
Song sheet	
Advertisement	
Stamps	
Map	
Money	
Ballot paper	
$u_1 = 17$	$u_2 = 2$

Figure B2. *Participant HM responses for uses of paper where u_1 and u_2 are respectively the number of suggested uses within each of the two categories required to calculate creativity quotient from Equation 2.*