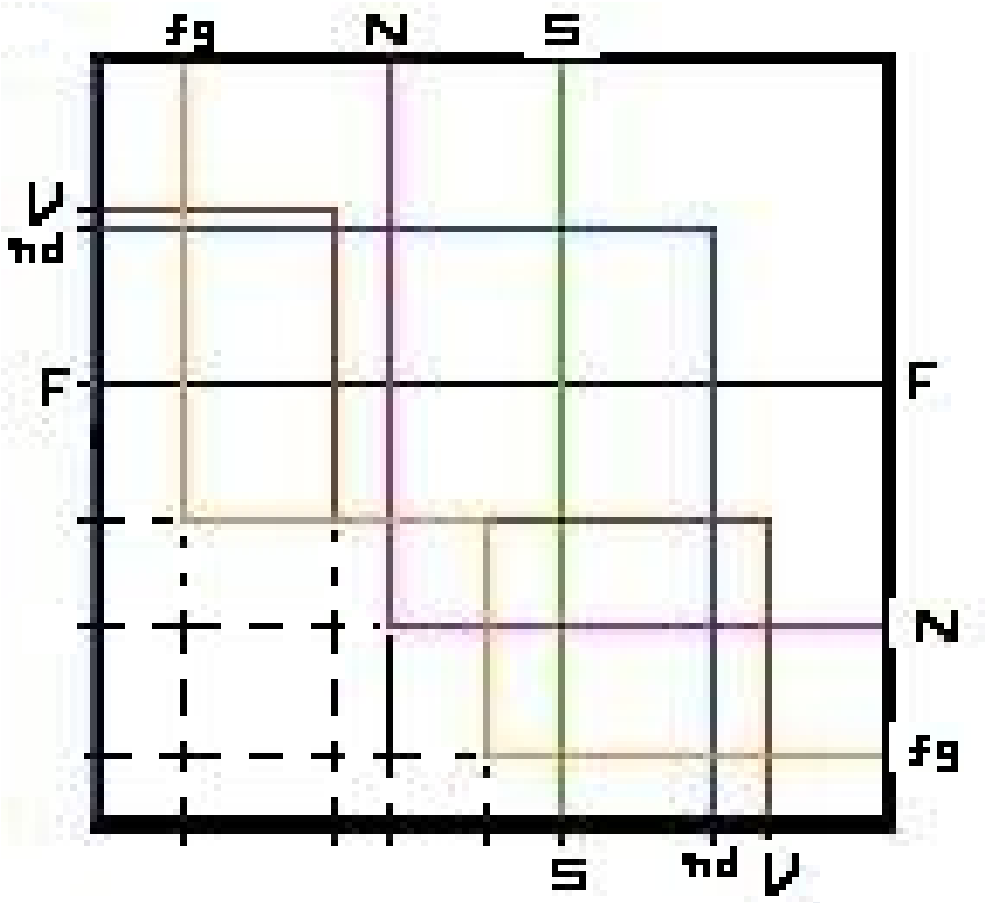
CREATIVITY

in problem solving



Samuel Shye **Irit Yuhas**

The Van Leer Jerusalem Institute

CREATIVITY

in problem solving

A Multidimensional Approach to its Definition and Measurement

Research Report Submitted to
The Israel Science Foundation

Samuel Shye **Irit Yuhas**

The Van Leer Jerusalem Institute

January 2004

Table of Contents

PART I. APPROACHING CREATIVITY		1
1. Creativity research: The background for this study		**3**
1. The origins of creativity research	3	
2. Innovation vs. Appropriateness	4	
3. The creative process	5	
4. Existing creativity tests	6	
5. Creativity and intelligence		
2. The Formalization of creativity		**12**
1. The facet approach to creativity research	12	
2. Objectives of this study	15	
3. Creativity: concept, definition and structure	16	
4. The Creativity Problem Solving Test (CPST)	23	
5. TTCT and its comparison with CPST	24	
6. Comparison of CPST with the inductive ability test (SKIT)		
3. Research procedure and method		**34**
1. Subjects	34	
2. Research instruments	34	
3. Test administration	35	
4. Data analysis	35	
PART II. STRUCTURING & MEASURING CREATIVITY		38
4. The Creative Problem Solving Test (CPST): Basic Statistics		**39**
5. The structure of creativity		**45**
1. The material facet	45	
2. The gestalt facet	47	
3. The material subspaces of creativity	52	
4. Conclusion: the creativity pie	59	
6. The measurement of creativity: The two essential coordinate-scales		**61**
PART III. COMPARING CREATIVITY: CPST vs. TTCT, SKIT		70
7. CPST & Torrance Test of Creative Thinking (TTCT): a comparison		**71**
8. Creativity by CPST in relation to inductive intelligence by SKIT		**79**
References		**84**

APPENDICES		
Appendix A. The Creative Problem Solving Test (CPST): The test and response distributions		
Appendix B. Torrance Test of Creative Thinking (TTCT): The test and response distributions		
Appendix C. The Shye-Klauer Inductive Ability Test (SKIT): The test and response distributions		

P A R T I

Approaching Creativity

For many years creativity was conceived to be a mystical quality attributable to geniuses, explaining their outstanding ability. Creativity has been envisioned as originating from divine inspiration and, hence, the common person cannot share in it, not even comprehend it (Burt, 1966; Razik, 1967). These attitudes towards creativity have hampered its study as a scientific subject. As a psychological phenomenon, however, creativity clearly merits a systematic study, requiring a scientific definition, one that would delineate the structure of the concept and enable its investigation and empirical assessment. Hence the need for a more formal and less intuitive definition of creativity, one that would lead to the formulation of testable hypotheses and theories, as well as enable a meaningful measurement of the concept (Guttman, 1982; Shye, 1978ab, 1985).

The social role of creative problem solving is difficult to overestimate. Newly arising problems in the social, economic and technological spheres often cannot be solved by resorting to conventional practices. In a fast changing world, the need for creative problem solving is becoming ever so urgent. Whether in educational settings, in organizational and economic spheres, or in the various branches of the government, new kinds of problems arise that must be, first, recognized, and then tackled in new ways. However in this context innovation is not an end in itself. Rather it appears as a way, sometime as the only way, to respond adequately to a challenging situation. Creative solutions, like any solution, must be evaluated not for their novelty but for their appropriateness; i.e., how well they meet the challenge confronted. But in the social context, as well as in the psychological one, creativity cannot be fruitfully investigated without clear conceptual framework that would help define the phenomenon, identify its constituent components, and propose instruments and procedures for measuring it. This is what the present study aims to do. However, this stage the investigation is limited to the study of creative problem solving, where by problem we mean a specific challenge that is presented by the external --the physical or the social --environments. A more comprehensive investigation based on the conceptual framework of this study would include problems that we describe as internal—those that are defined and tackled by the creative artist.

CHAPTER 1

CREATIVITY RESEARCH: THE BACKGROUND FOR THIS STUDY

1. THE ORIGINS OF CREATIVITY RESEARCH

Much of the psychometric approach to creativity is grounded in Galton's (1896) pioneering work (Burt, 1966; Vernon, 1970). Following Galton, further attempts at systematic creativity research were made by Binet and Henry (in Wakefield, 1991) who assessed creative imagination through responses to ink blots, the completion of drawings and stories, and the construction of sentences based on given words.

Despite these attempts, interest in the systematic study of creativity remained limited until the middle the 20th century. The starting point of modern creativity research is usually identified with Guilford's (1950) APA presidential address. In his address, Guilford described creativity as a combination of abilities shared, to some extent, by everyone the difference between those commonly considered creative people and others being a matter of quantity, not of quality. This observation helped bring down the notion of creativity from its lofty mysterious position and paved the way for its systematic study. Using Factor Analysis, Guilford (1959) attempted to identify the central components of creativity (equated with his "divergent thinking", as contrasted with convergent thinking, where a single correct response is sought, as in common intelligence tests). The factors with which he came up included: problem identification, fluency (the ability to produce many new ideas), flexibility (the ability to combine domains and abandon old ideas in favor of new ones), originality (the ability to come up with unusual responses), and new definitions (the ability to re-define a problem or find novel usage to a familiar object).

Guilford's works have led to the development of creativity tests based on the notion of divergent thinking. The tests are quite similar to each other. Some of them assess

fluency and flexibility by tasks similar to Guilford's original ones (e.g., composing words from a set of given letters), and some assess these qualities indirectly. The best-known battery is the TTCT (Torrance Tests of Creative Thinking, Torrance, 1974) which tests for fluency, flexibility, originality and the ability to elaborate on problems. The battery also distinguishes between the visual and the verbal domains. Its importance lies in its inclusion of tasks that are complex compared with those originally created by Guilford. TTCT scoring is performed on three scales matching Guilford's fluency, flexibility and originality. Later TTCT were further refined.

Surveying works since Guilford's, one finds multiplicity of definitions for creativity, so much so, that some scholars found it useful to address the question of definition classifications, rather than the definition itself. Mooney (in Taylor, 1988) identified four approaches to the study of creativity, each suggesting a different kind of definitions and different foci for research: the environment wherein the creative process takes place, the creative process, the creative product, the creative person. Taylor (1988) classified proposed definitions thus: gestalt definitions, stressing re-structuring of the perceptive pattern; innovation definitions, leaning on the quality of the end-product (as useful or satisfying to others); expressivity definitions, centering on people's need to express themselves in a unique fashion; psychoanalytic definitions and solution-thinking definitions, stressing the creative mental process (rather than the product).

Many scholars were impressed that the multiplicity of definitions for creativity -- and the lack of a theory-oriented definition combining the essential features of the many proposed ones-- substantially hamper progress in the study of creativity as a budding discipline (e.g., Hudson, 1966; Tardiff & Sternberg, 1988; Taylor, 1988; Taylor & Holland, 1964).

2. INNOVATION VS. APPROPRIATENESS

Upon examining extant definitions of creativity (over 50 definitions have been reviewed by us), we find two major recurrent themes: innovation and correctness (appropriateness). Innovation refers to new ideas, to new combinations of ideas, or to a new product. Innovation is regarded relative to the creating individual himself,

relative to a given social or cultural environment, or relative to human knowledge in general. Appropriateness refers to the quality of the creative product: the product must be "correct" in some sense--useful, efficient, or accepted by a certain group in society-- in order to be considered creative. The conjunction of both, innovation and appropriateness as components of creativity is explicitly mentioned in modern approaches. Sternberg and Lubart (1995) note that the creative product must be "novel" (original and different from other products normally produced by others, surprising and unpredictable) as well as appropriate (useful, or supplying a right answer to a problem). They claim that if not "appropriate", the product would not be considered creative but bizarre and irrelevant. Boden, (1996) suggests that creativity involves a new combination, interesting and valuable, of old ideas. Eysenck (1996) conceived of creativity as based on personality trait of "psychoticism" (innate tendency to develop psychosis under stress). He defined creativity as the ability to produce ideas, insights, inventions or original art works that are considered by experts to be of scientific, aesthetic, social or technical value. Gardner, (1988; 1993) presents an approach based on creative people life stories. He defined the creative person to be one who solves problems, shapes products or possesses new questions in a manner perceived as new, but becomes accepted in a particular cultural context.

3. THE CREATIVE PROCESS

Research on the creative process has focuses mainly of the attempt to understand components, or stages in that process. Most models refer to the stages proposed by Wallace (1926): preparation (data collection and conventional ways for reaching a solution); incubation (a latent process involving unconscious thinking), illumination (the emergence of an idea and a feeling of progress towards a solution); verification (where the solution is tested and elaborated). Guilford (1967) proposed that during the incubation stage information is being processed and unconsciously transformed. The transformed information reaches consciousness at the moment of the illumination. Medenick (1962) describes the creative person as one who tends to combine distant elements in a meaningful fashion. The creative person, according to Medenick, benefits from a host of associations and a cognitive ability to raise and develop unusual solutions.

According to Guilford, there are two major stages in the creative process. In the first, a mental search in various directions takes place. This is referred to as *divergent thinking.* In the second, thought is focused on logical rules leading to the most appropriate solution. This is referred to as *convergent thinking* (Guilford and Hoffner, 1971). Since then, creative thinking has been identified mostly with divergent thinking.

An additional model for the creative process has been proposed by Martindale (1989). This model relies on elements from the domains of attention, cognition, and neuropsychology. Martindale suggested that in concentrated attention a small numbers of adjacent cortical nodes reach a high cortical level, while other nodes are not active at all or active at a low level. This process corresponds to secondary thought process with structured associative hierarchy. In contrast, in situations where attention is widely distributed, a large numbers of connections are activated in a medium level. This kind of process take place in primary thought process such as those associated with dreaming.

According to this model, the insight stage becomes possible precisely when attention is widely distributed and communication is open in a wide associative alignment, hence increased alertness that comes with over motivation or extra efforts to concentrate and reach solutions may hamper creative thinking. This model has no direct empirical validation but is supports by indirect evidence. A similar approach has been proposed by Gruber (1985), who claimed that the creative process takes place when a weak connection exists between cognitive subsystems and so people whose thought patterns are solid and contains strong interconnections can not be great creators. The process as described by Martindale and Gruber can be related to the concept of Guilford's divergent and convergent thinking. Divergent thinking as involving moderate activation of distant cortical connections, while convergent thinking implies high level activation of adjacent cortical connections. In Characterizing creativity it seems that most researchers stress the notion of divergent thinking. Yet it seems to us that convergent thinking, too, plays a role in the creative process, for example, when ideas raised are examined with respect to their aptness.

4. EXISTING CREATIVITY TESTS

The leading creativity test today is Torrance test battery which contains ideas from the test created by Guilford (Torrance test of creative thinking, 1966, 1974). These tests contains verbal as well as the figural parts and testees are requested to raise diverse ideas and as many as they can, to situation presented. In each of the subtest (the verbal and the figural) scoring is based on a number of components: *Fluency*, which is evaluated by the number of given responses, and *originality* which is evaluated by the responses which have been determined to be relatively rare. In addition, in the verbal subtest, *flexibility* is evaluated as well by the number of different content categories, represented in the proposed ideas; and in the figural subtest, *elaboration* is evaluated by the extent of testee's ability to "develop embroider, embellish, carry out or otherwise elaborate ideas" but the actual scoring estimates the number of details in the given responses. Additional measures of the figural tests are the abstractness of titles given to figural responses, and "resistance to premature closure". Torrance test scores are obtained, then, on five scales in the figural subtest and on three scales in the verbal subtest. Like most tests inspired by Guilford, these tests are based on divergent thinking and lack an explicit manifestation of the notion of appropriateness. Also these kind of tests do not refer to the question of the structure of creativity but rather examine separate factors (Shye & Goldzweig, 1999). Another test of creativity is Medenick's (1962) Remote Associate Test (RAT). It is based of 30 items that probe into subjects' ability to create new associations among different elements. Thus, the farther apart the elements presented, the more creative is the process. In contrast to Torrance and Guilford tests, where the subjects is requested to provide as many responses as she or he can, subjects of RAT are requested to reach one correct answer. The result of this test is a single score representing Medenick's conception of creativity as the ability to find a connection between elements that are seemingly unrelated. The Advantage of this test is in its explicit reference to the notion of correctness. Its disadvantage is that it refers to verbal creativity only, and even here it is quite restricted in its scope and does not attempt to sample the entire universe of creative verbal ability. Nevo (1972) built a test of mental abilities that includes divergent thinking ability in three domains: numerical, verbal and figural. The test made explicit reference to the notion of correctness. Its disadvantage is that it is based on quantitative measures forgoing the requirement for novelty in proposed solutions

(for example: from a given set of numbers, create as many arithmetic exercises as possible). Getzels & Jackson, (1962) as well as Wallach & Kogan (1965), developed tests batteries for assessing divergent thinking essentially similar to those of Guilford and Torrance. An example test item invites subjects to name as many things as possible that move on wheels, or to list as many uses as possible for a chair, or for a paper and so on (Wallach & Kogan, 1965). The latter's test differs from Torrance's mainly in the conditions of test administrations: Wallach and Kogan claimed that the common procedure for conducting creativity test is inadequate and advocated test administration in a playful atmosphere, unrestricted in time.

Although new conceptions of creativity made some reference to the notion of aptness, appropriateness or even correctness, this development has not been reflected in creativity tests. These retained their focus on divergent thinking only and have not undergone significant improvements. Plucker & Runzuli (1999) Reviewed a wide criticism of existing creativity tests. Their main criticism is addressed to the absence of a clear distinction between creativity and other constructs as well as to low predictive validity concerning future creative achievements. Creativity tests developed on the basis of the proposed definitions have been the subject to considerable criticism, from the very beginning. Hudson (1966) claimed that most "open" creativity tests employed in the U.S. are ill conceived and do not measure creativity. Wallach and Kogan (1965) claimed that inter-correlations among the various tests are low. Wakefield (1991) suggested that the validity of Guilford's tests, based on divergent thinking, is dubious and claimed that a new research directions and a new theoretical framework is needed. Wakefield (1991) claimed, inter alia, that tests requiring problem definition or re-definition are better correlated with creative achievements outside the test domain than tests based on Guilford's factors (see also Cooper, 1991). Also, it seems that Guilford's own proposed test tasks are simplistic. (E.g. fluency is assessed by counting answers to a given question, and flexibility by counting categories to which responses belong.)

Another problem is that in many of the existing tests scoring is largely subjective. Many of these tests examine fluency in defining creativity. Indeed, as noted, fluency as well as flexibility and originality are relevant aspects of creativity but in themselves they do not insure neither novelty nor appropriateness of the proposed idea. Without testing for these features (novelty and appropriateness) one may obtain a flux of

meaningless ideas which cannot be regarded as creativity; or to obtain many good ideas that are nevertheless well known, representing no novelty. Also, even if we accept that fluency is an aspect of creativity, it is not clear that such fluency must be conscious. It is its quite possible that a subconscious fluency exists, and the responses that emerge have underdone initial subconscious filtering. In this respect there can be considerable interpersonal differences in thinking style and personality inclinations. The notion of originality, defined as rare response, is also problematic: original ideas need not to be new, can be bizarre and lack meaningful contribution.

Boden (1996) observes that in fact, the testing-psychometricians may well perform implicit judgments of the worth of responses, when they grade novel responses as creative. She stresses that a positive evaluation of responses constitutes a part of the very meaning of creativity and hence must be addressed explicitly. Thus we may conclude that in spite of increasing awareness of the importance of appropriateness in defining creativity, these notions are not adequately (and jointly) represented in current creativity tests of which Torrance's is the most widespread. Torrance test refers to appropriateness only indirectly by discarding ideas that are totally irrelevant, but not by explicit scoring. Other tests which do refer to appropriateness do not adequately refer to novelty. Finally, most existing tests refer to certain domains of creativity, typically verbal and figural, neglecting other domains such as social or interpersonal and symbolic-numerical.

5. CREATIVITY AND INTELLIGENCE

The question of the relationship between creativity and intelligence and whether they tap similar abilities, have attracted the attention of many scholars. As there is no consensus on the meaning of creativity, it is no surprise that on this question too, opinions are very diverse. Some researchers, like Getzels & Jeckson (1962), emphasize the distinction between these two constructs, intelligence and creativity. By classifying subjects, these researchers created two distinct groups, one of students with high IQ and relatively low scores in creativity tests, the other of students with high creativity scores and relatively low score in intelligence tests. Results of the study have shown that scholastic achievements in the two groups were equal in spite of the difference in the IQ score which was a bout 23 points on the average. Following these

findings, the researchers concluded that intelligence and creativity make separate contribution to scholastic achievement and hence that the two constructs are distinct. Milgram & Milgram (1976) reached a similar conclusion when they found that among high school students in Israel, those who reported much activity in creative domains (such as music, science, social leadership etc) scored highly in creative thinking test but their intelligence score and their school grades were not higher than those of ordinary students. Research approaches of this kind focused on the difference between creativity and intelligence but there remained the question of the relationship between these two constructs.

The common way to measure human intellectual abilities is by means of the Wechsler Test. Guilford (1967) claimed that tests of this kind examine only the ability to recall that which has been learned or to recognize it in new situations. Using Factor Analysis, Guilford proposed what he called the structure of the intellect (SOI) which consisting the factors that make up the intellect. Guilford classified these factors into three classes: operations, contents, products. The content factors included figurative symbolic semantic-verbal and social behavior. This latter factor was added by Guilford on theoretical basis, so as to represent social intelligence. One of the operations that Guilford defined and which he regarded as representing creativity is divergent thinking and includes the search for information and offering a large number of responses to a given problem. This is in contrast with a single correct answer, which he identified with convergent thinking. Guilford's approach implies that creativity is but a subset of intelligence although he noted that usually divergent thinking items are not included in intelligence tests but only convergent thinking items. Hence, as long as intelligence is identified with and measured by a test such as Wechsler's, creativity is not in fact a subset of intelligence. A widespread approach today concerning the relationship between creativity and intelligence sees a certain overlap between the two, in some senses but not in other senses (Sternberg & Lubart, 1999). Baron (1963) who supports this approach claims that if one defines intelligence as the ability to solve problems, then, in solving problems on a high level, intelligence is expressed through originality. Sternberg and O'hara (1999) present a series of findings that suggest that creative people get above average IQ score, and often about 120. Among those of IQ above 120, there is almost no linear relationship between intelligence and creativity, while among those with lower IQ there is a low but positive correlation. Simenton

(1994) and Sternberg (1996) explained that high IQ may hamper creative thinking ability because high intelligence people are awarded for analytic skills. Hence, they do not develop their creative potential which may remain only latent. Medenick's (1962) approach, according to which the creative process involves the creation of new associations among existing elements, relies on the observation that the creative solution depends also on a body of relevant knowledge as well as the ability to organize associations. These abilities are considered to be part of intelligence. Medenick sees a strong connection between creativity and intelligence, stemming from a conceptual overlap of these two domains.

Yet another approach depicts intelligence as a sub-domain of creativity. While a minimum level of intelligence is essential for creativity, additional attributes are necessary as well. Sternberg and Lubart (1991) investment theory proposed, six origins for creativity: intelligence, knowledge, intellectual style, personality, motivation and environmental context. According to this theory, all six components are required for creativity, but some mutual compensation is possible as well. Aspects of the intelligence are of special relevance for creative thinking: the ability to define a problem, selective coding (distinction between relevant and irrelevant information) selective combinations (constructing combinations of relevant pieces of information) and selective comparisons (novel associations between old and new pieces of information). As an example they presented Bohr's model for the atom as a miniature solar system. The model derives from the insight of selective analogy associating the atom and the solar system. Simenton (1984) pointed to an additional connection between knowledge and creativity. His findings showed that creativity is related to intelligence by an inverse U shape graph, indicating that creativity reaches its height when one is in the course of acquiring knowledge in the relevant domain. That is, high levels of knowledge can have adverse effect. It seems that in spite of the great progress made in creativity research there is no agreement on the nature of the relationship between creativity and intelligence. The difficulty stems from the fact that these constructs themselves are neither similarly understood by researchers nor is their measurement performed in a uniform way.

A new perspective on the relationship between intelligence and creativity was proposed by Shye and Goldzweig (1999). See below.

CHAPTER 2

THE FORMALIZATION OF CREATIVITY

1. THE FACET APPROACH TO CREATIVITY RESEARCH

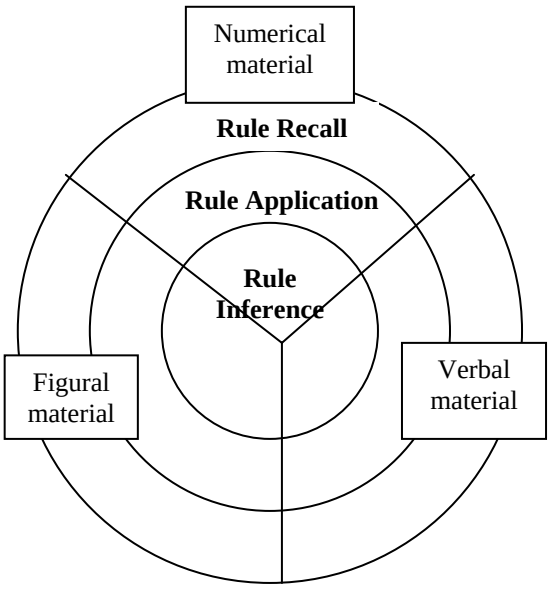
Shye and Goldzweig (1999) anchored the concept of creativity within the structure of intelligence as conceptualized in facet theory, using Guttman's radex theory and the notion of cognitive complexity. Facet theory (Shye, 1999; Shye and Elizur , 1994) has been developed by Guttman and his colleges as a meta theory for discovering lawfulness and theory construction and the behavioral sciences. The advantage of the facet paradigm is in its ability to overcome problems of conventional statistic such as sampling of variables or scale validation. In modern facet theory (Shye, 1998) the investigated concept is likened to continues body in space, each of whose points, represents a variable of that concept. The concept is defined by the universe of all variables for its measurements, while the variables actually observed, are considered to be but a sample taken from that universe.

Thus, facet theory offers a new scientific imagery that focuses on conceptual-spatial continuum. The depiction of this continuum is based on a similarity coefficient (often correlations) computed between the variables, but these computations are done only for propose of mapping variables as points in space. Every other point is considered to represent a possible variable that has not been actually observed. Data Analysis is preformed by faceted small analysis which partitions the space according to conceptual classifications of the variables. This new imagery offers a natural way of formulating, investigating and answering the question of the relationship between the concepts of intelligence and creativity, as well as the question of the internal structure of creativity.

Based on Guttman's (1965) conceptualization, one defines intelligence in terms of its items: An item belongs to the content universe of intelligence if and only if the item

asks about a subject's performance in a cognitive task and the items response is evaluated according to its correctness with respect to objective rule (Shye and Elizur, 1994). Guttman's radex theory of intelligence empirically validates a two way classification of intelligence: By the material facet (numerical, verbal, figural), and by the cognitive-task facet (Recall, application, or inference of an objective rule). As can be seen in Fig. 2.1, as one parts from the center of the circles towards the periphery, the distances between items of different materials can become larger. The fact that rule recall appears in the outer ring and rule inference in the inner ring reflects the fact that rule inference tasks differentiate less than rule recall tasks among the kinds of materials. That is, an individual who does well in rule recall in one kind of material, will not necessary do well in rule recall in another kind of material. However, one who excels in rule inference in a certain material has a good chance to succeed in rule inference in other materials as well. An important concept here is that of cognitive task *complexity* which is represented by increasing differences in a series of task characteristics (It should be noted that the notion of task complexity differs from that of task *difficulty*; the latter is assessed *a posteriori* by the rate of success or failure in task performance and is population-relative (Guttman, 1954; Shye, 1985)).

Fig. 2.1. Guttman's Radex Theory of Intelligence: The Intelligence Space is Partitioned into Sectors by the Material Facet and into Concentric Rings by the Cognitive Complexity Facet



In their study of inductive (rule-inference) ability Shye and Klauer (1993) proposed a detailed content analysis for the concept of complexity based on increasing differences and decreasing similarities in the characteristics of the cognitive tasks. In a series of cognitive tasks, imitation is the least complex, and inference is the most complex, the later representing the greatest accumulation of characteristics having the value of "D" (difference). See Table 2.1, lines1-4.

Shye and Goldzweig (1999) proposed to extend the complexity continuum so as to allow for the concept of creativity. They defined creativity as an invention of a new *kind* of rule, one that is not known in advance and is not implied from the context which the individual operates. This is in contrast with rule inference were the specific rule sought is new but is of a known type or of a type implied in the context of the operation. This formulation of the concept of creativity is manifested by an extrapolation of the cognitive complexity continuum, as shown in the line 5 line of Table 2.1.

Table 2.1. Content Analysis of Cognitive Task Complexity as Accumulation of Differences in Task Traits

Line			Learned/ response time pts	Learned/ expressed response	Known/ invoked rule	Stimuli inter-relation ship	types of Inter-relationships	Known/ invoked kind of rule
1	Imitation		S	S	S	S	S	S
2	Rule Recall		D	S	S	S	S	S
3	Rule Application		D	D	S	S	S	S
4	Rule Inference	Generalization	D	D	D	S	S	S
		Discrimination	D	D	D	D	S	S
		Classification	D	D	D	D	D	S
5	Rule invention		D	D	D	D	D	D

Using this definition for creativity, the Shye and Goldzweig (1999) extended Guttman mapping sentence for intelligence and Shye and Klauer's mapping sentence of inductive ability to the domain of creativity. According to their analysis, rule invention is conceived as part of the continuum of tasks, one that is more complex than the tasks of rule inference. This led the researchers to hypothesize that rule invention would be found in a ring even more internal than that of rule inference and would differentiate less among the kinds of materials than the task of rule inference.

From another angle, a possible affinity between creativity and intelligence is described by Shye (1985) in his re-analysis of cognitive test data by Nathan and R. Guttman (1984). Using Partial Order Scalogram Analysis (POSAC), Shye hypothesized that imagination (divergent thinking) would be polar opposite to convergent thinking in the following (POSAC-) sense. While convergent thinking items were actually found to play an attenuating role (i.e., high scores on them assure a certain minimum in each of the scalogram axes--the verbal ability *and* the spatial ability), divergent thinking items were hypothesized to play an accentuating role (i.e., high scores in them assure very high standing in at least one of scalogram axes, the verbal *or* the spatial). This hypothesis was clearly supported in a preliminary study (Shye and Goldzweig, 1999). It suggests that high intelligence in at least <u>one</u> domain is a necessary condition for creativity, a conclusion that throws new light on the findings reviewed above in Chapter 1.

2. OBJECTIVES OF THE THIS STUDY

1. To contribute to the formalization of creativity research:
    a. To present a new conceptualization of creativity, and an operational definition for creative problem solving as a mental ability;
    b. to create a test for creative problem solving ability;
    c. to test hypotheses of the structure of creativity;
    d. to propose procedure for the measurement of creative ability.
2. To examine the relationship between the new test for creative ability and the veteran Torrance Test of Creative Thinking (TTCT);
3. To examine the relationship between the new test for creative ability and a test of Inductive ability (SKIT), representing an aspect of intelligence.

3. CREATIVITY: CONCEPT, DEFINITION AND STRUCTURE

1. Creative Problem Solving

"Necessity is the mother of invention" says the proverb, and indeed this may well apply to the invention of a new kind of a rule. The invention of a new kind of a rule is the essence of creativity, according to the definition proposed by Shye and Goldzweig (1999) and adopted in this study. Hence the creative act is manifested in response to a dire need, to a challenge or a problem that cannot be otherwise solved. According to this view the intelligent person, when faced with a problem, tackles it in the simplest and most straightforward way he or she can. "Simplest" also in the technical sense of low mental function, i.e. retrieving a solution from one's memory, if the solution is there (="rule recall"). If it isn't there, the would-be solver, turns to applying some known procedure for reaching the solution, if indeed he or she is aware of such a procedure (="rule application"). If, however the would-be solver is not aware of such a procedure, he or she might turn to the more complex task of inferring the solution from some known examples that can be considered analogous to the problem posed, but grounded in the context of that problem (=inductive thinking, or "rule inference"). Finally, if no rule of a known type can help solve the problem, the would-be solver turns to inventing a rule –a procedure, or a new kind of analogy—that enables him or her to identify an acceptable solution (=creative thinking or "rule invention"). The invention itself consists of raising very openly a number of ideas, sometimes by remote associations and partial analogies (divergent thinking). Then, the solver evaluates and sifts candidate solutions by the criterion of appropriateness and the most appropriate one is proposed as a solution.

It is worth noting in passing that the process of "divergence-convergence " or of "shake and sift" is present also in the wider context of social (and biological) reality, where ideas are raised, new behaviors spring, and new phenomenon come into being ("mutations") in a disorderly manner, or even by chance. Those phenomena that adequately respond to a certain (recognized) need or a problem, are retained. In this

study however we focus on creativity as the personal ability to solve problems through rule invention, when the simpler cognitive procedures would not do.

We have noted earlier that the concept of creativity has been recognized to consist of two major characteristics: Novelty and appropriateness. Thus in assessing a solution we would presumably have to take account of both, how new it is and how appropriate it is. It is important to point out that in the context of defining creativity it is not enough to refer to novelty in general, but rather to specify that the novelty must be with respect to the kind of rule that has been discovered. The discovery of a new rule of a known kind would not qualify as a manifestation of creative ability. Certainly, the discovery of a new solution by a known procedure would not qualify either. On the other hand, in the context of psychological testing (as opposed to the context of social settings) novelty is to be interpreted relative to the problem-solver as an individual. I.e., the rule discovered is of a novel kind if the individual respondent has not been previously exposed to it, i.e., to this *kind* of a rule. Thus in composing a test for creative problem solving ability, one should attempt to verify that the problems included, do in fact require the discovery of a new kind of a rule on the part of the intended subjects, and cannot be solved by these subjects in any other—simpler—way. Technically, our strategy would be to have the "novelty" requirement built into the test items, while appropriateness or correctness would be the criterion for evaluating the response given by the subject. The challenge of creating items where the novelty is built-in (i.e., items that in the tester's estimation cannot be solved by the intended testees using simpler mental functions) is not easy but is not unlike the one faced by testers in intelligence tests, where the tester attempts to probe into testee's ability to infer a new rule of a known type (i.e. one must verify that the testees indeed are unaware of that rule). Or, in the case of rule application items, where one must be sure that testees actually go through the process of applying the rule and do not simply memorize the result. A bonus of this strategy is that the semantic design of the creativity test agrees with Guttman's design of intelligence test—the responses are evaluated with respect to a single criterion, that of correctness, thereby enabling comparison as well as integration of these two concepts. However, it is important to stress that correctness, in the case of creativity is intended in its widest sense containing notions such as usefulness, aptness, appropriateness, according to the problem posed. Thus, in the case of creativity items, the notion of correctness is

typically much softer than in the cases of items of simpler mental functions such as recall and application (although some loosening of this notion is apparent already in the case of rule inference items, where more than one solution is sometimes possible).

Finally we note that the concepts developed in this study may well apply to the domain of artistic creativity as long as one assumes that this kind of creative behavior can be cast in terms of problem solving. In Art, the "problem" is typically defined by the artist himself and in an implicit manner. Hence the application of the present conceptualization to artistic creativity requires a special and separate attention, and will not be dealt with in this study.

Using the facet theoretical device of mapping definition (Shye & Elizur 1994), we define creative problem solving formally in terms of the test items that make it up, thus:

> **An item belongs to the universe of creative problem solving if and only if its domain requires inventing an objective rule (finding an objective rule of a new kind) in a given material and its range is ordered from very correct to very incorrect.**

Here, the question of what constitutes a new kind of a rule, is a central challenge of this study, and will become clearer as we proceed. Initially, the term *kind of a rule* is intuitive, given the context in which the testing takes place. The notion of correctness is intended in a very wide sense, as explained above.

2. Facets of Creativity

Having portrayed the universe of creative problem solving items, it is of interest to classify these items into categories that reflect the essential kinds of creativities. The proposed classifications, in turn, will form the basis for hypotheses concerning the structure of creativity and, further, the basis for its actual measurement. We therefore turn now to specifying two different classification, or *facets*, of creativity: The *material* facet and the *gestalt* facet.

The Material Facet. The kind of material to which the cognitive operations are applied (be they recall, rule applying, rule finding or rule invention) is an important aspect of any mental ability testing. Guttman's radex theory of intelligence refers to three major kinds of material: verbal, numerical and spatial. In addition, social material is referred to in the works of Gesell (1949), Guilford (1967) among others. The question of kinds of material is the focus of Gardner's (1983) theory of multiple intelligence where the kinesthetic and psycho-social domains are invoked as well. Although real life situations present intellectual challenges that have rich mixtures of materials, the search for scientific lawfulness has largely guided researchers to formulate and test hypotheses concerning "pure types". Thus, a clear lawfulness emerges in the semantic space of intelligence which is found to be partitionable into three sectors corresponding to the verbal, numerical and figural materials (Schlesinger & Guttman 1969; Snow et al 1984, Shye 1988). In their study focusing on inductive (rule inference) ability, Shye and Klauer (1993ab) have added a fourth kind of material, the interpersonal, arguing that it is needed to complete a 2X2 cartesian pattern thus: whereas the figural and numerical fields can be conceived of as originating in the physical environment, the interpersonal and the verbal materials have their origin in the social environment. And, whereas the figural and the interpersonal fields are relatively concrete manifestations of their respective environments, the numerical and the verbal are more symbolic. Thus the four element material facet can be portrayed as a 2X2 table. See Table 2.1. Content analysis provided the rationale for a corresponding regional partition of the empirical semantic space (obtained by FSSA). This structural hypothesis was indeed repeatedly confirmed in rich data. In a study that attempts to extend these findings to creativity it seems reasonable to adopt these four kinds of material.

Table 2.1. The Material Facet (figural, verbal, numerical, interpersonal) Decomposed into Two Basic Facets: Environment and Symbolization (Shye and Klauer, 1993 p. 185-186)

		Functioning Environment	
		Social Environment	**Physical Environment**
Level of Symbolization	**High**	Verbal material	Numerical Material
	Low	Social material	Figural Material

The First Creativity Structural Hypothesis: The Circle of Materials. The four elements of the material facet, the figural, the numerical, the verbal and the interpersonal, will be found to be distinct from each other and spatially interrelated by an angular partition of the creativity space, i.e. they would form a circle in space.

Rationale for this hypothesis is grounded in the above content analysis summarized in Table 2.1. A similar hypothesis has been supported in a study of inductive ability (Shye and Klauer, 1993) as well as in preliminary investigations preceding this study.

The Gestalt Facet. The second proposed facet is characteristic to creative problem-solving and strives to probe into the essence of the creative thinking. In any problem posed to testee, there are elements that stand out as essential or central, and there are those that are incidental or peripheral. In the mental depiction of the problem, the former can be considered as pertaining to the "figure", and the latter as pertaining to its background. Initially, when faced with a problem, the respondent assigns, to elements of the problem differential roles-- as pertaining to the figure or to the background (unnoticed elements or relations are considered to be at the far background). This assignment can be more or less automatic, or more or less implicit. Reviewing many instances of rule invention tasks, we observed that their solution require *re*-assignment of elements of the given problem to the figure or to the background. This unexpected shift in the gestalt formation of the problem is what makes the problem a creativity item.

The gestalt facet classifies creativity items according to how drastic is the reassignment of the figure and background roles. In particular, a distinction can be made between problems whose solution require no more than such role-reassignment of elements that are within, or very close to the context of the problem as presented; and problems whose solution require importing to the "figure" elements that are not hinted in the problem, or those pertaining to a very far background. In the former case, one must identify and flexibly exchange between elements of the background

and element of the figure of the stimuli presented. In the latter case, one must introduce a new dimension for solving the problem.

Let us illustrate the distinction between the (relatively) low complexity of figure/ground inventive task and the high complexity of new-dimension-inventive task, by the following two numerical items. An example of a low complexity item:

Problem: The 2 numbers within the following pairs are similarly related. How?

(0.375 512) (0.25 4) (0.6667 9) (0.2222 81)

Solution: *In each pair of numbers, the second number [b] is obtained from the first, [a,] in 2 steps: in the first step, the first number [a] which is a decimal fraction, is converted into a simple fraction, [s/t (a≈s/t)]. In the second step, the denominator of that fraction is raised to the power of the numerator: [t ^ s] and so we obtain the second number in the pair [(b = t ^ s)]. For example let's look at the first pair.*

0.375 = 3/8 → 8^3 = 512

I.e., first, 0.375 should be recognized as 3/8. Then 8 is raised to the power of 3, to get 512. And similarly for the other pairs:

0.25 = 1/4 → 4^1=4; 0.6667≈ 2/3 →3^2=9; 0.2222≈ 2/9 → 9^2=81

Example of a high complexity item:

Problem: The 2 numbers within the following pairs are similarly related. How?

(459 3) (181 2) (2145 4) (876 1)

Solution: *The second number specifies the position of the greatest figure in the first number. For example, in the first pair, the 3 indicates that in the number 459, the greatest figure, 9, is located in the third position.*

While both these items are creativity items in that they require the discovery of a new kind of a rule, yet the first remains within the context of algebraic computation and hence is relatively simpler. What is required is to bring the simple fraction representation of the given decimal fractions from the background to the fore. The second, however, requires introducing a meaning (that is, *ordinality* of numbers, to be used for designating location) that is far removed from the usual arithmetic meaning

of numbers. Discovery of that new dimension requires a departure of the context of a given problem and may well be considered as representing a large mental distance. Our assumption is that there is in fact a continuum of mental distances in this facet but at this stage of research a dichotomous distinction would suffice.

We refer to this facet as the mental distance facet or as the *gestalt facet*. It represents the distance of the mental connection that must be made in order to obtain the required new kind of a rule.

The Second Creativity Structural Hypothesis: Conflicting Centralities. Both theoretical deliberations and empirical results have led to two competing hypotheses. Both hypotheses specify that the gestalt facet is radial, i.e., they anticipate that the creativity space would be partitionable by a circle into two regions, the one containing the "close context" (or "figure/ground") items, the other containing the "far context" (or "new dimension") items. The two hypotheses conflict, however, with respect to the anticipated locations of the two types of creativity items:

The one hypothesis, considering the "new dimension" items to be more cognitively complex, expects those items to be located within the inner circle; and the simpler, figure/ground items, to be on the outer ring. Thus the rationale for this hypothesis is based on the notion of cognitive task complexity developed and supported in previous studies of intelligence, inductive, and creativity (Shye & Goldzweig, 1999). The other hypothesis anticipates, on the contrary, that the new dimension items would be in the external ring, and on the average, farther apart from each other, while the figure-ground would be located in the center of the radex, and on the average closer to each other. The rationale for this spatial configuration is that problems that require importing element from far away, require ready access to basic knowledge (akin to the less complex mental function of rule recall) so as to enable the solver to form novel combinations for inventing a rule of a new kind. Detailed knowledge in specific domains or expertise, if viewed and used in a flexible manner can enhance creative solutions. However, expertise in diverse materials is rare in one person and would tend to place new dimension creativity problems further apart from each other than figure/ground creativity items would be. The latter, those with short mental distance, require reference to contents closer to the problem in its given context, and

information combination that are less rare and therefore maintain stronger relationship among themselves. Hence such items would be in the inner circle.

In view of the seemingly conflicting hypotheses and their rationales, the question of the structural role of the gestalt facet is left for exploratory analysis.

4. THE CREATIVITY PROBLEM SOLVING TEST (CPST)

The CPST composed in the framework of the present study and shown in Appendix A, contains a selection of items from each of the four classes of material (figural, verbal, numerical, interpersonal) from each of the two classes of the gestalt facet (figure/ground, new dimension). That is, eight sub-universes of the creativity universe are represented. All items are designed to require the invention of a new kind of a rule and responses to them are assessed as to the degree of their correctness, or appropriateness. The definitional framework for the creative problem solving items can be schematically presented by the following mapping sentence:

Testee (X) performs a task requiring the invention an objective rule by

introducing $\begin{Bmatrix} figure/ground\_shift \\ New\_Dimension \end{Bmatrix}$ **in a** $\begin{Bmatrix} figural \\ verbal \\ numerical \\ interpersonal \end{Bmatrix}$ **material** $\longrightarrow$ **in a**

$\begin{Bmatrix} very\_correct \\ . \\ . \\ . \\ very\_incorrect \end{Bmatrix}$ **manner**

5. TTCT AND ITS COMPARISON WITH CPST

A second purpose of this study is to investigate the relationship that hold between two creativity tests: Torrance test of Creative Thinking (TTCT) and The Creativity Problem Solving Test (CPST), the new rule invention test constructed as part of this study. Since TTCT is the most widespread creativity test today it seems important not only to compare the definitional and theoretical basis of these two tests but also the empirical relationships between them. This is in spite of the fact that by their respective definitions, the two tests do not intend to measure the same constructs.

Torrance defines creativity as "a process of becoming sensitive to problems, deficiencies, gaps in knowledge, missing elements, disharmonies and so on; identifying the difficulty; searching for solutions, making guesses, or formulating hypotheses about the deficiencies: testing and retesting these hypotheses and possibly modify and retesting them; and finally communicating the results." Torrance and his associates have developed several batteries of test activities for use in all cultures, from kindergarten through graduate and professional school. In their tests, they tried to use activities that reflect the creative processes, each involving different kinds of thinking, so that each test would contribute something unique to the batteries under development. The activities in these tests are supposed to represent the important kinds of creative thinking required in daily life and of creative breakthroughs. Following a description of TTCT we will compare it with our new CPST.

1. Description of TTCT

TTCT consists of two sub-tests, the verbal and the figural. Following is a summary descriptions of the tests based on Torrance (1982) and Torrance et al. (1990,1992).

(i) Torrance's Verbal Test (Six Activities)

The "ask and guess" activities (activities: 1-3). The ask activity is designed to reveal the individual's ability to sense what one cannot find out from looking at the picture and to ask questions that will enable to fill the gaps in one's knowledge . The guess-

causes and the guess-consequences are designed to reveal subject's ability to formulate hypotheses concerning cause and effect. The number of relevant responses produced by the subject gives the measure of fluency; the number of different categories of questions, causes or consequences gives the measure of flexibility; and the Statistical infrequency of these responses--questions, causes or consequences--gives the measure of originality. These measures are taken in the same way for all other activities in the verbal tests. (See Appendix B.)

The fourth activity is **product improvement**. Torrance sees this activity as one of the most dependable measures. He claims that most subjects find it an interesting task and that this task permits "to regress in the service of the ego" and to play with ideas they wouldn't dare express in more serious tasks.

The unusual uses activities. This task is based on Guilford's task and is in part a test of the ability to free one's mind of a well establish set: the "cardboard boxes" creates in many individuals rigid sets that are difficult to overcome. It is easy to define them as "containers" and to find many "container" responses, but it is harder to produce other kinds of responses.

The "just suppose" activity. This task, too, is a modification of Guilford's test task. The subject is confounded with an improbable situation and is asked to predict possible outcomes from the introduction of a new variable. In order to respond productively to this task, the subject must "play with" the possibilities and imagine other things that would happen as a consequence. Torrance notes that this kind of thinking can be intolerable to many individuals.

(ii) Torrance's Figural Test

The figural test consists of three activities each of which is supposed to represent a different creative tendency. There are five different measures for these activities including *fluency,* which represents the subject's ability to produce a large number of figural images. This score is obtained by counting the number of different relevant alternatives. The *originality* score represents the ability to produce uncommon or unique responses. This measure is based on lists containing the most common

responses which, if given by a subject are counted as 0, while other responses are counted as 1. The *elaboration* measure reflects the subject's ability to develop, embroider and to elaborate ideas. This measure is obtained by estimating the number of details and placing within one of six given number intervals pre-determined by normative data. *Abstractness of titles* measures the ability to sense the essence of the problem, to know what is truly essential. This is reflected in the level of abstraction given to the title of the pictures drawn. It is defended as part of the figural battery on the grounds that it requires the transformation of figural information to another modality. The measure of *resistance to premature closure* is based on the assumption that creative behavior requires a person to "keep open" in processing information and to consider a variety of kinds of information.

The picture construction activity sets in motion the tendency toward finding a purpose for something that has no definite purpose and elaborates on it so that a purpose is developed. The measures for this activity are: Originality, abstractness of titles and elaboration.

The Picture completion activity calls into play the tendency toward structuring and integrating and gives an opportunity for in-depth presentation of a single object, scene or situation. According to Torrance, this activity creates tension in the beholder who must control this tension long enough to make a mental leap necessary to get away from obvious and commonplace response. Failure to delay gratification can result in premature closure of the incomplete figures and obvious or commonplace response. The invitation to make the drawing tell a story is designed to motivate elaboration and further filling in of gaps in information. The measures for this activity are: fluency, originality, abstractness of titles, elaboration, and resistance to premature closure.

The Repeated lines activity involves the requirement to return to the same stimulus again and again, perceiving it differently each time, disrupting order in order to create something new. The measures for this activity are: fluency, originality and elaboration.

2. Comparing TTCT and CPST

The following *mapping sentence* integrates the conceptual frameworks of both the CPST and TTCT test items. It would assist us in highlighting the differences between the two tests. The main differences may be summarized as follows.

1. In the material facet (see Facet C in the mapping sentence below), CPST uses all four kinds of material, the figural, the verbal, the numerical and the interpersonal; whereas in TTCT only the figural and the verbal materials occur. Yet, examining TTCT verbal subtest closely it appears that it contains items that are truly social; in fact pure verbal items, referring to semantic or syntactic contents, are missing in TTCT. In relating the two tests empirically it would be of interest to find out how, specifically, the figural subtests and the verbal subtests of the two tests are related. Also in view of the above observation, it would be of interest to observe the relationship between CPST interpersonal and TTCT "verbal" subtests.

2. TTCT, anchored in processes identified as instrumental for creative thinking, is based on six different measures for such processes (fluency, originality, flexibility, elaboration, abstractness of titles, resistance to premature closure) used selectively and in different combinations, for the overall assessment of creative thinking (e.g. surprisingly, flexibility, argued to be an important aspects of creative thinking, is not measured in TTCT figural test). CPST, in contrast, focuses on the outcome. It seeks to assess creative problem-solving ability, a notion that hinges on the concept of appropriateness of the response, skipping, in effect, the mental processes that might have led to the given response.

3. Although in TTCT responses are evaluated with respect to various measures, the questions, or stimuli, presented to subjects are not a priori classified (beyond the material facet), foregoing, in effect, the opportunity for developing hypotheses concerning the structure of creativity. In CPST, on the other hand, items systematically represent creativity tasks of two kinds: figure/ground and new-

dimension (f/g and ND) as specified by the gestalt facet. (Yet, although not intended by TTCT, responses can be classified after the fact as representing f/g or ND).

The combined mapping sentence is:

The extent to which Subject (X) demonstrates

Facet A | Facet B | Facet C

$\{Appropriateness, fluency, flexibility, originality, elaboration, abstracness, resistance\}$ **in a task of** $\{f/g\_shif, new\_dim, object\_construction, pattern\_compl., outcome\_mult., inquiry, interpretation, projected\_outcome, object\_improvement, new\_application, imag.\_consequences\}$ **in a** $\{figural, verbal, numerical, interpersonal\}$

material

$\rightarrow$ $\{very\_high, ., ., ., very\_low\}$ **in the sense of an element of Facet A**.

Facet A in the above mapping sentence lists the criteria that serve directly to assess creative behavior in the two tests. Its first element, appropriateness, is the criterion for assessing creative behavior according to CPST, the other six elements (fluency, flexibility etc) are those used in TTCT for assessing creative behavior. However in TTCT not all six are measured with respect to both sub-tests: In the figural test the measures used are fluency, originality, abstractness of titles, elaboration and resistance to premature closure, but flexibility is not measured (although it seems possible to conceive of such a measure in figural material). In the verbal test the measures used are fluency, flexibility and originality, and it is not clear why the other measures are absent here.

Concerning Torrance's measures themselves, several questions can be raised. For example, since the different measures are assessed with respect to the same specific task, the fluency score constitutes an upper bound to the other measures, and so may introduce a built-in dependency between the measures. Also, with regard to the notion of elaboration, it is not clear why elaborate responses represent creativity, for often creative responses are marked by their surprising simplicity and even minimalism.

Facet B lists the modes of thinking that the specific test items require of the testees. In CPST there are two such modes Figure/Ground and New Dimension. In TTCT, it is the kind of task required of the testees. The terms used here, however, are not Torrance's but rather our translations of Torrance's terms intended to fit Torrance's both kinds of material, the verbal and the figural. For Torrance's terms are material-specific: Thus, Torrance's task of "picture construction" is represented here by "object construction", to allow for the possibility (not materialized in TTCT) of constructing objects in other kinds of material. The task of "picture completion" in TTCT is, again, specific to the figural test and no analogous task is offered by TTCT for the verbal material (although it is possible to think of such a task in verbal and other materials as well). Here we termed this task "pattern completion". Similarly, Torrance's "repeated line activity" confined to figural material, is labeled here "outcome multiplicity", a term which can serve analogous tasks in other kinds of material. The remaining six elements of Facet B (inquiry, interpretation etc) are again our terms for Torrance's tasks. All six occur only in Torrance's verbal test and not in his figural test, although it seems that analogous tasks in the figural material (as well as in other materials) could be devised.

Facet C lists the kinds of materials to which test items refer, and has been discussed above.

Finally, the Range Facet (Response Facet) lists the scores obtainable on the various measures, whether they refer to CPST (appropriateness) or to TTCT (fluency etc). The meaning of this facet is derived from the relevant element from Facet A. I.e. The range-facet assesses the degree of appropriateness, the degree of fluency, etc. While TTCT uses a range facet of multiple meaning, CPST is so designed that (without

loosing heterogeneity in contents, which is relinquished and built into the stimuli themselves) all items hinge on a single concept, that of appropriateness.

In principle, one could consider the mapping sentence presented above as delineating a grand content universe encompassing both, creative process a-la-Torrance and creative outcome, in line with our present approach. While a systematic study combining both creative processes and outcome could be of interest, in this study, the conceptualization and the measurement of creativity itself is based on the outcome alone, according to our approach.

To conclude, in our view the classical tests based on those by Guilford and by Torrance suffer from theoretical flaws that concern, first and foremost, the very definition of creativity: There is no direct reference in these tests to the concept of appropriateness, essential to the notion of creativity. True, appropriateness has a more open significance in creativity than, say, in recall tests or intelligence tests, but it is nevertheless essential for the assessment of creativity. Instead, the classical tests focus on processes that could, according to one possible conception, facilitate and promote creative behavior. But this is a roundabout and unsure way to assess creativity itself, for it is not clear whether these processes suffice or whether, additional qualities are necessary as well. Moreover, it is not even clear that *they* are indeed necessary, since there just may be more than one way of being creative (or more than one specific set of traits that enable creative behavior). In contrast, the test developed here (CPST) hinges on evaluating the outcome, namely appropriateness, regardless of how it was obtained, of the responses to problems that by their very definition and construction require creative ability for their solution.

Furthermore, in the theoretical framework of classical creativity testing, no hypothesis is advanced concerning the relationship among factors of creativity, not even between the main ones proposed (fluency, flexibility, originality). *A-fortiori*, no hypotheses are proposed with respect to the system of interactions among them (for example as represented by the inter-correlation matrix), or the structure of the creativity concept. But such a structure is important for any theory of creativity and for its scientific measurement. CPST, based on a formal rationale for the definition

of creativity, suggests specific hypotheses concerning the structure of creativity as detailed above.

What empirical relationships can be expected between TTCT and CPST? Since the conceptual bases of the two creativity tests is so different, it is not easy to formulate detailed hypotheses concerning their relationship. The study of their relationship will be left for exploratory analysis. Nevertheless, general hypotheses can be made as follows. First, that in the combined space encompassing both the processes measures in TTCT and the outcomes evaluated in SPCT, a clear partition would be visible between items of the two tests. The rationale for this hypothesis is simply that the one test, TTCT, refers to measures of creativity processes while the other test, CPST, refers to appropriateness of outcomes. Second, since two of the four kinds of material in CPST are outwardly similar to the two kinds of material in TTCT, we can expect the affinity between similar materials to show up somehow in the structure of the joint space.

6. COMPARISON OF CPST WITH THE INDUCTIVE ABILITY TEST (SKIT)

As elaborated upon in Chapter 1, creativity is fashioned here as a conceptual extension of intelligence, with the two concepts being distinguished by their degree of cognitive complexity (See Table 1). In this study the empirical relationship between intelligence and creativity will be examined, where intelligence is represented by its more complex cognitive task, namely, rule inference (inductive ability) as measured by SKIT (Shye and Klauer, 1993).

The mapping sentence in this case is simple:

The extent to which Subject (X) performs a cognitive task requiring

$$\begin{Bmatrix} rule\_\text{inf}erence \\ rule\_invention \end{Bmatrix} \textbf{ in a } \begin{Bmatrix} figural \\ verbal \\ numerical \\ \text{int}erpersonal \end{Bmatrix} \textbf{ material} \longrightarrow \textbf{in a } \begin{Bmatrix} very\_correct \\ . \\ . \\ . \\ very\_incorrect \end{Bmatrix}$$

manner

A basic hypothesis that follows from our conceptualization of creativity relies on the distinction shown in Facet A. The hypothesis is that creativity as defined would be distinguished from inductive ability. Namely, that items requiring the discovery of a rule of a (presumably) *known* kind would be structurally distinct from items requiring (by our construction) the discovery of a rule of a *new* kind. This hypothesis would be supported to the extent the space of both these abilities is partitionable into two distinct regions, each dominated by items of one of the tests (SKIT and CPST). The confirmation of this hypothesis would lend support to reasonableness of our approach, as it would underscore the fact that in spite of the seemingly strong similarity in the definitions of inductive ability and creativity, and in spite of the difficulty that may be encountered in delineating the line between a rule of a known kind and a rule of a new kind, creative ability stands as a formally defined, separate concept.

A refinement of this hypothesis refers to the shape of the expected partition, once it has been established. As in the case of the gestalt facet (within creativity, see Chapter 1), here, too, two different structural outcomes can be rationalized: first, that creativity would be located within a circle, while the inductive ability would be located in an outer ring surrounding that circle. This expectation follows from extending the well established radex theory of intelligence, noting that creativity is the more complex cognitive function. The other possible outcome, is the other way around—the inductive ability would be at the center. The rationale for this outcome relies on the observation that creative thinking relies on the accessibility to rich and detailed knowledge with which one can play around. (The rationales for these two hypotheses is strictly analogous to those proposed in the case of the gestalt.) In empirical data, both outcomes have received some support in earlier or preliminary studies (Shye and Goldzweig, 1999; Yuhas, 2002, respectively). Our hypothesis, then, is that the partition between creativity and inductive ability would be radial, i.e., a circle would separate the two. The question of which of the two would be at the center is left for exploration.

The material facet, too, gives rise to a possible hypothesis: namely that some separation by its elements would be apparent regardless of the origin of the items –

hether inductive ability (SKIT) or the creativity test (CPST). A more stringent hypothesis would anticipate, in addition, that the partition pattern would be angular, and with the circular order dictated by the analysis of the material facet by its basic facets (See Table 2.1).

CHAPTER 3

RESEARCH PROCEDURE AND METHOD

1. SUBJECTS

295 students participated in this study. They form four groups: 80 from 10^{th} grade of high school; 36 from the 12^{th} grade of high school, 127 university students from various departments and a special group of 52 high school graduates all high achievers in the sciences. All groups took CPST, the new creativity test composed in the framework of this study, and the inductive ability test, SKIT (Shye & Klauer, 1993). The first three groups took also TTCT.

2. RESEARCH INSTRUMENTS

1. The Creative Problem Solving Test (CPST)

CPST consists of four sub-tests of figural, verbal, numerical and interpersonal materials. Each sub-test contains 8 problems, or puzzles, four of which requiring invoking "new dimension" for their solution, and the other four requiring figure/ground shift. Thus the test consists of 32 items. Responses were coded as incorrect (or inappropriate) (score 1); partly correct (2); or correct (3). See Appendix A.

2. The Torrance Tests of Creative Thinking (TTCT)

TTCT consists of two tests the Verbal (Form A was used here) and the Figural (Form A). Torrance's Verbal test included six tasks each of which is evaluated with respect to fluency, flexibility and originality. A Total Fluency score was obtained, according to Torrance's procedure, by summing the six fluency scores, and then transforming them to obtain a Standardized Total Score for Fluency. Standardized Total Score were similarly obtained for flexibility and for originality. The average of the three standard

scores was computed as well, to obtain a total for the verbal test. Torrance's Figural includes three activities. According Torrance's procedure, Activity 1 was evaluated by originality and elaboration. Activity 2 was evaluated by fluency originality, abstractness of titles, elaboration and resistance to premature closure. Activity 3 was evaluated by fluency, originality and elaboration. Standard Total Score are then computed for each of the five measures. The average of the five standard scores was computed as well, to obtain a total for the figural test. Finally, the total scores in the verbal and figural tests were averaged to obtain a total score in the TTCT. See Appendix B.

3. Shye-Klauer Inductive Ability Test (SKIT)

In this study, a short version of the original SKIT was used, consisting of 62 items: 18 in the figural, 15 in the interpersonal, 15 in the numerical and 14 in the verbal. Responses were coded as in CPST. See Appendix C.

3. TEST ADMINISTRATION

Tests were administered in two meetings. In the first meeting SKIT and TTCT were taken and in the second, CPST. The times allotted for the tests were: 60 minutes for SKIT, 45 minutes for verbal Torrance test, 30 minutes for the figural Torrance test and 90 minutes for the CPST, divided into two parts of 45 minutes each: the figural and verbal in the first part and numerical and interpersonal in the second.

4. DATA ANALYSIS

1. Basic Statistics

Response distributions and means are computed for the three tests of this study (CPST, TTCT and SKIT) as well as for their sub-tests. These are presented in Chapter 4 and in the Appendices.

2. Correlation Coefficients

Statistical correlation coefficients were used for the overall assessment of the relationships between CPST and TTCT, and between CPST and SKIT, as well as for assessing the interrelationships between subtests of these tests.

3. Faceted Smallest Space Analysis

Structural hypotheses concerning creativity, its distinctness from intelligence, its internal structure, and its relationship to other concepts, were all tested by Faceted Smallest Space Analysis (Shye, 1999; Shye and Elizur, 1994). Smallest Space Analysis (SSA; Guttman, 1968) is a computerized Multidimensional Scaling technique that aims, as well as possible, to map variables as points in a geometric space of a given dimensionality, so that the greater the similarity index (usually correlation coefficient) between two variables, the closer are their points in the space. In Faceted SSA, the variables observed are interpreted as a sample from all possible variables of the content universe investigated, and their points in space are used as indicators for delineating regions of homogeneous contents. Having mapped variables in a geometric space, Faceted SSA computer program (Shye, 1991) partitions that space into regions according to a prior classification (=facet) of the variables. The program can refer to three kinds of model partitions: the axial model (partitioning by parallel straight lines); the angular model (partitioning by radii emanating from a point); and the radial model (partitioning by concentric circles). For each model the program computes the Separation Index indicating how well the data fits that model. The Separation Index can range between 0 and 1, with 1 indicating that the model perfectly fits the *a priori* content classification of the variables.

4. Partial Order Scalogram Analysis by base Coordinates (POSAC)

Based on the understanding of the structure of creativity, a meaningful measurement becomes possible. Measurement, in the present multidimensional context, means the mapping of individual testees along coordinate-scales whose number is the smallest possible, given the complexity of the concept measured. In practice what we aim to do is preserve the observed order relationships between all pairs of profiles (lists of

scores). By order relationship we mean both the relationship of “greater than” (e.g. 22212 > 21212); and “incomparable to” (22221 $ 11112, to be read: 22221 is incomparable to 11112). Thus the (in)comparability relationships between score-profiles, as defined here are considered the basic information that must be preserved in the process of reducing the dimensionality of the measurement space and identifying measurement scales.

POSAC/LSA Computer program yields a plot of all testees, each represented by a point in a two dimensional coordinate space so that each testee gets two new score, x and y. These new scores are computed so as to optimally represent the order relationships --incomparability as well as comparability (“greater than”)-- observed for all pairs of testees’ profiles. The measurement-theoretical challenge in POSAC is the interpretation of the coordinates by assigning them psychologically meaningful concepts. This is done using the auxiliary programs LSA1 and LSA2, as well as by studying the program’s *item diagrams* partitioned by step-curves so as to optimally separate between categories of the item in question (Shye,1985; Borg and Shye, 1995).

Based on the structure of creativity to be discovered by Faceted SSA, composite variables will be computed by averaging all items pertaining to each kind of creative ability that will be identified. These composite variables, in turn, are the ones processed by POSAC/LSA, to yield two new creativity score for each subject on the two interpreted coordinate scales.

P A R T I I

Structuring &
Measuring Creativity

CHAPTER 4

THE CREATIVE PROBLEM SOLVING TEST (CPST): BASIC STATISTICS

In this chapter we present some basic statistical data concerning The Creative Problem Solving Test (CPST) as it was administered to the samples described in Chapter 3. Since this is the first time that CPST is being administered, our purpose is to learn something about how difficult the test is and how sensitive it is to testees' traits. Since the main thrust of the present study is the structure of creativity and its multidimensional measurement, we will look at the descriptive statistics only in very general terms.

Mean scores in the CPST were computed for the four sample groups described in Chapter 3 (Research Procedure and Method), and for four groups defined by the major subject taken in school (or university). Table 4.1 presents the results. Here the means are computed over the eight items in each subtest and hence can range between 8 and 24. As can be seen, the average score for all testees in all tests is 13.0, which means that on the average subjects scored about one third of the total score possible: (13-8)/(24-8)=31.3%. The lowest mean score in the table is that of the 10^{th} graders in the verbal subtest: 10.0 (representing a performance of 12.5%); and the highest was of the Special science high school graduates, in the numerical subtest: 16.3 (representing a performance of 51.9%). The maximal and minimal scores obtained by individuals in each of the tests are also given in the table.

The results show that 12^{th} graders did better on CPST than 10^{th} graders; and that university students did better than 12^{th} graders. The special, highly select group of high school graduates in the sciences, received the highest average score. These results do not, of course, suggest that creativity increases with age (especially if we note that group 3 is younger than group 4). Rather, results are consistent with the claim that creativity increases with motivation and with general intellectual ability. 12th graders in Israel, facing their national matriculation examinations, can be argued to be more intellectually alert than their younger comrades. University students are

both, a group selected out of the 12th grade for its general ability and a group situated in an intellectual milieu. This can account for their performance exceeding that of the 12th graders. Finally, the special group of high school graduates in the sciences, nationally selected for their excellence and motivation, did better than all others in the CPST.

Out hunch is that age as such does not play a simple role in creativity. On the one hand, the young, when faced with a problem, or a puzzle, tend to play more with possibilities, dare to take risks and invest time in untreated paths; they are less inhibited by experience. On the other hand, the young may lack the basic knowledge necessary for approaching certain problems (the acquisition of knowledge takes time, and hence is likely to go with increasing age). The role of previous experience and expertise in creative problem solving ability is discussed in other sections of this report.

In high school as well as in the university, each student usually has major subjects of study. We have created four groups defined by the kind of "major subject" studied: whether in the humanities (literature, history etc), Physics and Mathematics (including computer science), Life sciences (biology and related fields), or the Arts (Theater, cinematography, music etc). In the few cases that a testee had a double major he or she would appear in both groups.

We found that students who major in the sciences, whether in physics/math or in the life sciences, received the highest CPST score (13.8 and 13.7 respectively, based on the average scores in the four subtests), while those who major in the humanities and the arts received a score of 12.6, each. In terms of performance percentage, this would be 36.25% vs. 28.75%, if we compare physics/math with the humanities, for example.

In Israel, especially in high school, the humanities are generally considered to be less prestigious and students are often directed to this major not so much for their competence in the literary or verbal domains as for their perceived insufficient ability in mathematics and in the natural sciences. The prestige, and presumed "talent" required for high school major in biology is popularly considered to occupy an intermediate position between the two, physics and humanities. However it is quite

possible that students in the humanities and in the arts are creative in a wider sense than the one measure by our Creative Problem Solving Test, a sense that includes, for example, creativity in music, in the arts or in writing. If so, their creative ability would not be manifested by a test of the present kind. CPST focuses on problem solving, and more importantly on problem solving of an *external* nature: the problem, whether in the figural or the numerical material, but even if it is in the verbal or interpersonal material, is typically "out there". Artistic creativity, we claim, can, too, be formulated in terms of "problem solving." However the problem in such a case resides mostly within the mind of the creator-- the artist, the musician or the writer. In fact, typically, the artist defines the "problem" before or as he or she solves it. Assessment of the appropriateness of solutions offered in artistic works in not impossible and is often attempted by art critics who judge a piece of art as being more or less "convincing", "relevant," moving", or any other description that is intended to evaluate its appropriateness. Should such internal problem-solving test be devised, students in the humanities and in the arts might have a better chance at higher scores. Nevertheless, the present CPST is not irrelevant to the creative arts as well, since at least some part of the creative artist's work must of necessity involve dealing with materials and means (physical objects quantities, language) that pertain to the external world. And, moreover, such means are intricately and inseparably involved with the main problem or message that is at the focus of an art work—consider the painter's or the sculptor's language of space or the poet's use of words. In the course of the artistic-creative process, dealing with these materials may require creative problem solving in the external realm. To the extent this is indeed the case, the present test may well reflect relevant artistic abilities.

Another angle from which CPST touches on artistic creativity is its inclusion of creative problem solving items from the verbal and especially from the interpersonal domains. These, although definitionally distinct from internal personality problems that seek their formulation and resolution, by their nature do touch the internal domain. Human relations, sampled by the interpersonal material and by the human verbal language, play a crucial role in the definition of internal processes and problems as well as in formulating and communicating to society their creative resolution.

Hence we turn now to a brief examination of the differential outcomes in the CPST subtests. We find that, not surprisingly, physics/math majors get the highest score both in the figural and in the numerical subtests. In both these subtests the life sciences majors follow at the second place, while the humanities and the arts trail behind. What is surprising, however, is that in the verbal and interpersonal subtests life sciences majors exceed all others! For, prima facie and for reasons outlined above, we would expect art and humanities majors to take the lead here. In an interesting way this expectation is *partly* met: It is not the physics/math majors that are first in these two human-oriented domains, refuting a simplistic (but not spurious) hypothesis that the physics/math majors are just better in everything. (Note especially that they score third on the interpersonal test!) But it seems that there is an indication here that perhaps *some* of those who choose the humanities or the arts do so as a default, not for their love or their ability in these fields, for otherwise the art and humanities majors should be the ones to top the verbal and/or the interpersonal tests.

To conclude, the descriptive statistical analyses indicate that while the CPST is not an easy test and it leaves sufficient room for detecting exceptionally capable students, it is fairly sensitive to external traits such as stage of studies, major subject of studies, and belonging to a highly select group (sub-sample 3).

Appendix A presents the response distributions for each item, in each of the groups and in the entire sample.

Table 4.1. Creative Problem Solving Test (CPST): Mean Scores and Standard Deviations for Selected Groups of Testees
(possible score range: 8-24)

Sub-sample		CPST (4-test average)	Figural	Verbal	Numerical	Inter-personal
1 (10^{th} grd)	**mean**	**11.2**	**12.5**	**10.0**	**11.6**	**10.9**
	sd	1.5	2.7	2.2	2.0	2.5
	range	*8.5-14.8*	*8-20*	*8-15*	*8-18*	*8-17*
2 (12^{th} grd)	mean	**12.5**	**13.1**	**12.1**	**13.0**	**12.0**
	sd	1.8	3.0	3.0	3.0	2.4
	range	*9.3-15.5*	*8-21*	*8-18*	*8-20*	*8-18*
3 (Sci grads)	mean	**14.5**	**13.9**	**13.5**	**16.3**	**14.2**
	sd	1.4	2.6	2.8	2.8	2.2
	range	*10.8-17*	*8-19*	*8-21*	*10-23*	*9-21*
4 (univ. stu)	mean	**13.5**	**13.2**	**13.3**	**12.9**	**14.8**
	sd	2.2	3.3	3.2	3.0	3.4
	range	*9-21.3*	*8-23*	*8-23*	*8-20*	*8-24*
All	mean	**13.0**	**13.1**	**12.3**	**13.2**	**13.3**
	sd	2.2	3.0	3.2	3.1	3.3
	range	*9-21*	*8-23*	*8-23*	*8-23*	*8-24*
Major School Subject						
Humanities	mean	**12.4**	**12.6**	**12.0**	**12.2**	**12.9**
	sd	2.1	2.7	3.1	2.8	3.6
range		*8.5-18.3*	*8-21*	*8-20*	*8-20*	*8-24*
Physics/math	mean	**13.8**	**14.1**	**12.8**	**15.0**	**13.4**
	sd	2.1	3.0	3.2	2.9	3.1
	range	8.8-21.3	8-22	8-23	10-23	8-22
Life Sciences	mean	**13.7**	**13.5**	**14.0**	**13.5**	**13.9**
	sd	2.0	3.7	3.2	3.4	3.1
	range	*9.8-18*	*8-23*	*8-22*	*8-20*	*8-20*
Arts	mean	**12.2**	**12.6**	**11.3**	**11.4**	**13.6**
	sd	1.8	2.8	2.8	2.5	3.2
	range	*8.8-17.3*	*8-19*	*8-20*	*8-17*	*8-20*
All	mean	**13.0**	**13.1**	**12.3**	**13.2**	**13.3**
	sd	2.2	3.0	3.2	3.1	3.3
	range	*9-21*	*8-23*	*8-23*	*8-23*	*8-24*

Table 4.2a. Statistical Significance of the Differences Between the Mean Scores of Sample Groups (*V*= significant at 0.05 level)

Between:	Figural Subtest	Verbal Subtest	Numerical Subtest	Interpersonal Subtest	CPST 4-subtest Average
10th & 12th grd	-	*V*	*V*	*V*	*V*
10th & Special	*V*	*V*	*V*	*V*	*V*
10th & Univ. Stu.	-	*V*	*V*	*V*	*V*
12th & Univ. Stu.	-	*V*	*V*	*V*	*V*
12th & Special	-	-	-	*V*	*V*
Special & Univ.	-	-	*V*	-	*V*

Table 4.2b. Statistical Significance of the Differences Between the Mean Scores of Groups of Major Subject of Studies (*V*= significant at 0.05 level)

Between:	Figural Subtest	Verbal Subtest	Numerical Subtest	Interpersonal Subtest	CPST 4-subtest Average
Phys & humani	*V*	*V*	*V*	-	*V*
Phys & Life Sci	-	-	*V*	-	-
Phys & Art	*V*	*V*	*V*	-	*V*
Humani & Life	-	*V*	*V*	-	*V*
humani & Art	-	-	-	-	-
Life Sci & Art	-	*V*	*V*	-	*V*

CHAPTER 5

THE STRUCTURE OF CREATIVITY

1. THE MATERIAL FACET

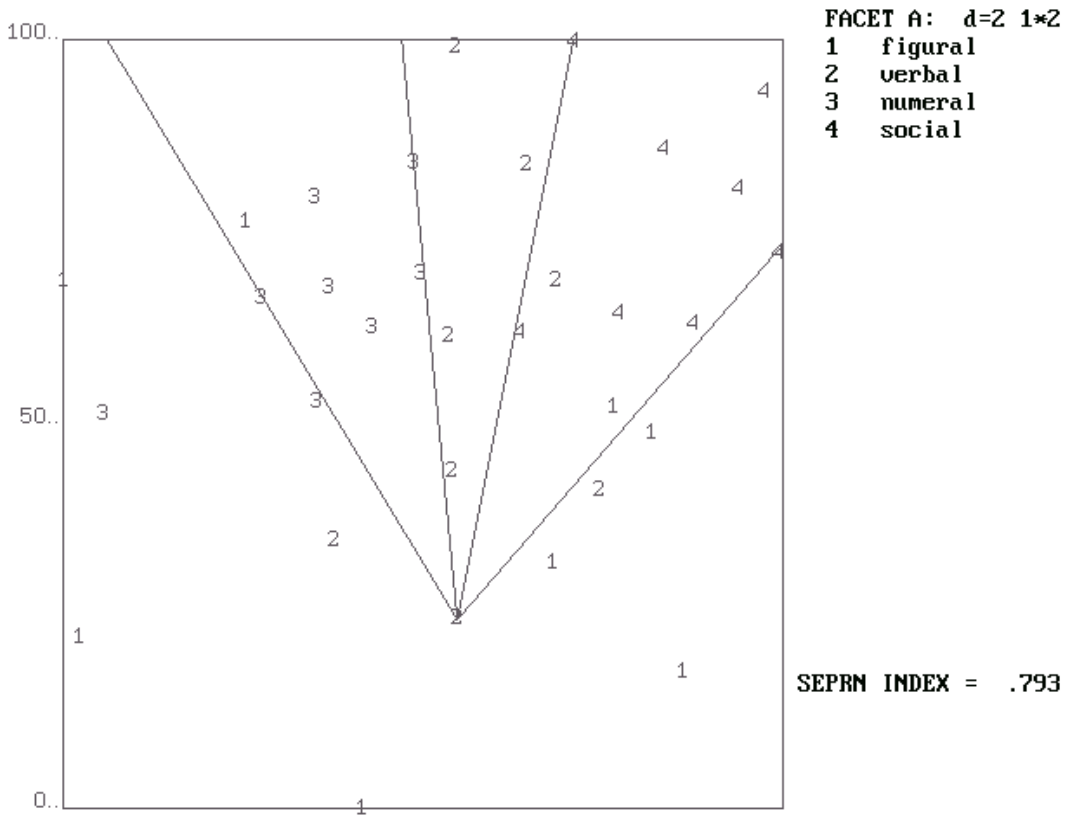
The first hypothesis concerning the structure of creativity states

a) That the items pertaining to each of the material types: figural, verbal, numerical and social, would occupy a distinct and separate region within the Creativity Space.
b) That, moreover (assuming part (a) is confirmed), the four regions would be arranged in a circular order with the verbal opposite the figural and the social opposite the numerical.

The rationale for this hypothesis has been presented in Chapter 2, and Table 2.1.

Results of Faceted Smallest Space Analysis of 32 creativity items, 8 for each of the kinds of material, confirm this hypothesis: Indeed, the map can be partitioned into four distinct regions, each of which contains (mostly) test items of one kind of material. See Fig 5.1. The extent to which this last statement holds true is indicated by the separation index which can range between 0 and 1, with 1 representing perfect separation. Here its value is .774 indicating a good fit between the item classification by their material facet and the partition of the map into regions obtained by the Faceted SSA computer program. Part (a) of the hypothesis is thus confirmed.

Fig. 5.1. Creativity Space Partitioned by the Material Facet
Supports the Material Facet Decomposition into two Elementary Facets
The Environment (Social/Physical) and Symbolization (High/Low):
The verbal ability is opposite the figural and the numerical is opposite the social



In studying the map in Fig 5.1 we note that the figural items (indicated by the 1's) are spread in the "creativity space" more widely than the other kinds of material. This phenomenon need not affect the structural conclusion that may be drawn from the results. Yet, it is of interest to attempt to explain this phenomenon. The first explanation that comes to mind is that the relatively wider spatial spread of the set of figural items reflects the item sampling in this study. Namely, that the sampling of the figural test items happened to be more extended than the sampling of the other kinds of material. This may be an outcome of the researchers' greater ability to produce items that are more varied in the figural material than in the other kinds of material. Alternative, a second kind of explanation would rest on the claim that figural items are in their very nature more varied than items pertaining to the other kinds of material (verbal, numerical social).

Now that Part (a) of the hypothesis is confirmed, we can turn to examining Part (b): Are the regions arranged in the "Creativity Space" as predicted, reflecting the 2X2

anticipated structure? Since the figural sector is so expanded that it crowds the other three sectors, the answer is not immediately visible. But a simple observation, that the 2X2 facet combination is essentially equivalent to a sector order of: figural -> numerical-> verbal -> social->figural, reveals that this circular order is clearly manifested. Thus, Part (b) of the first hypothesis is also confirmed, lending support to the theoretical consideration that led to the 2X2 scheme. This is in accordance with findings in Shye & Klauer (1993ab) concerning inductive ability.

2. THE GESTALT FACET

The second hypothesis states that the creativity space can be partitioned to reflect the distinction between two kinds of creativity items: Those whose solution rests on elements patent in the problem as presented, the challenge being in reassigning the roles of "figure" and of "ground" to these elements, versus those items whose solution requires bringing in an element or elements from different context. Our a-priori classification of the CPST items into FG (figure/ground) or ND (new dimension) is given in Table 5.1. (See CPST items and their classification in Appendix A).

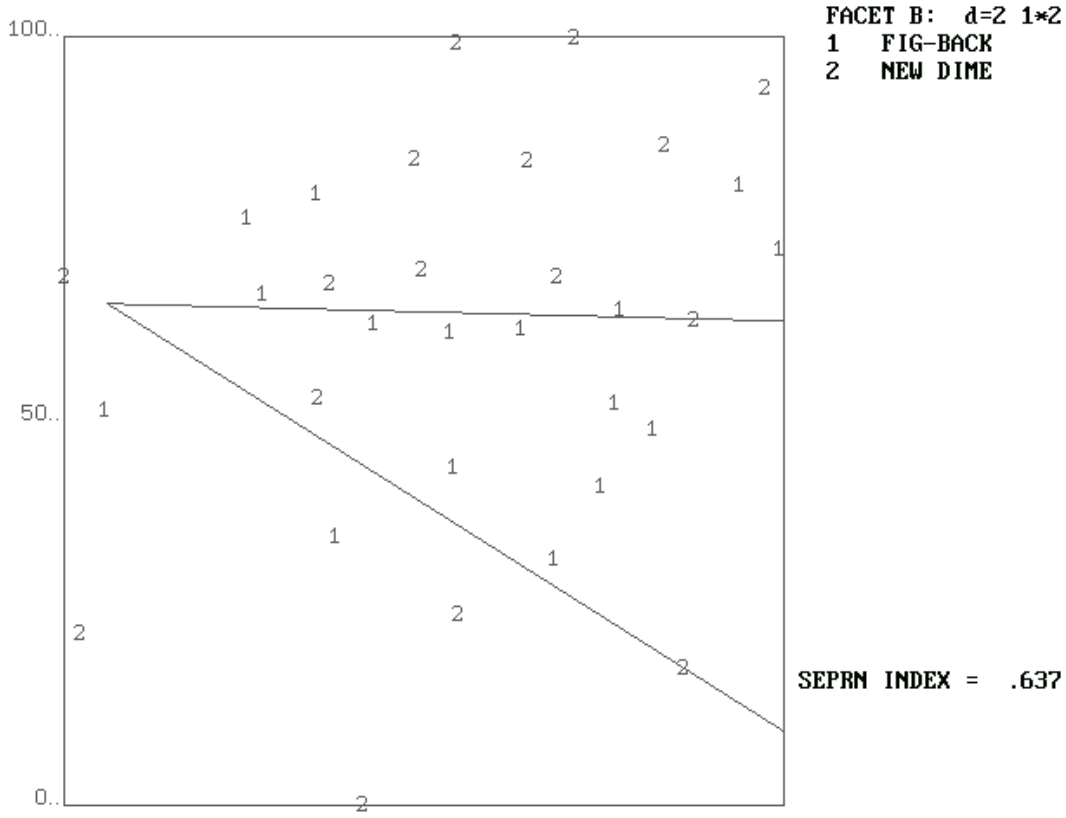
Table 5.1. A priori Classification of CPST Items by the Gestalt Facet {figure/ground vs. new-dimension}

Item No. within subtest	Figural	Verbal	Numerical	Interpersonal
1	**FG**	**ND**	**ND**	**FG**
2	**ND**	**ND**	**FG**	**ND**
3	**FG**	**FG**	**ND**	**ND**
4	**FG**	**ND**	**FG**	**FG**
5	**ND**	**FG**	**ND**	**FG**
6	**ND**	**ND**	**FG**	**ND**
7	**ND**	**FG**	**FG**	**FG**
8	**FG**	**FG**	**ND**	**ND**

We expect this facet, the gestalt facet, to be *radial,* i.e. the two sets of items would be separated by a circle. Which set would be found in the center? Although previous pilot studies were not entirely consistent in this matter some showing that the more complex items (those invoking a different context) are within the inner circle (e.g. Shye and Goldzweig, 1999); other studies (e.g. Yuhas, 2002) present a reverse picture: the more complex creativity items are in the periphery. In principle, based on theoretical considerations expounded above we expected the former pattern to hold.

Results of Faceted Smallest Space Analysis of 32 creativity items, 16 for each of the two gestalt formations, included the three maps that Faceted SSA produces, each examining the fit of the facet to one of three partition models—the axial, the angular and the radial. Of the three, the angular model has shown the best, and fairly satisfactory, facet separation (separation index=.67). See Fig. 5.2a.

**Fig. 5.2a. Creativity Space Partitioned by the Gestalt Facet:
The Angular Model Supports the Distinction between Figure/Ground Reassignment and Invoking "New Dimension"**



Adopting the angular model in this case implies that the sampling of the "new dimension" items is deficient and that a more balanced sampling would produce an angular partition pattern whose center is close to the center of the map. We are inclined to reject such a conclusion, not because we are confident that the item sampling is adequate but because of a deeper theoretical reason: If both, the material and the gestalt facets are angular then it is likely that they are conceptually dependent. This is clearly untenable, for the theoretical analysis indicates--and the item construction illustrates—that the two facets (classifications) cross, that is, they are conceptually independent. In any case, abandoning the radial hypothesis is not warranted at this stage. Since the radial model produced by the FSSA program (which is restricted to perfect circles) yielded an unsatisfactory separation index of .41 (see Fig. 5.2b, we turn to exploring afresh the effective partition pattern in this item diagram.

Fig. 5.2b. Creativity Space Partitioned by the Gestalt Facet: The Strict Radial Model (perfect circle as partition curve) Does Not Conclusively Support the Distinction between Figure/Ground Reassignment and Invoking New Dimension

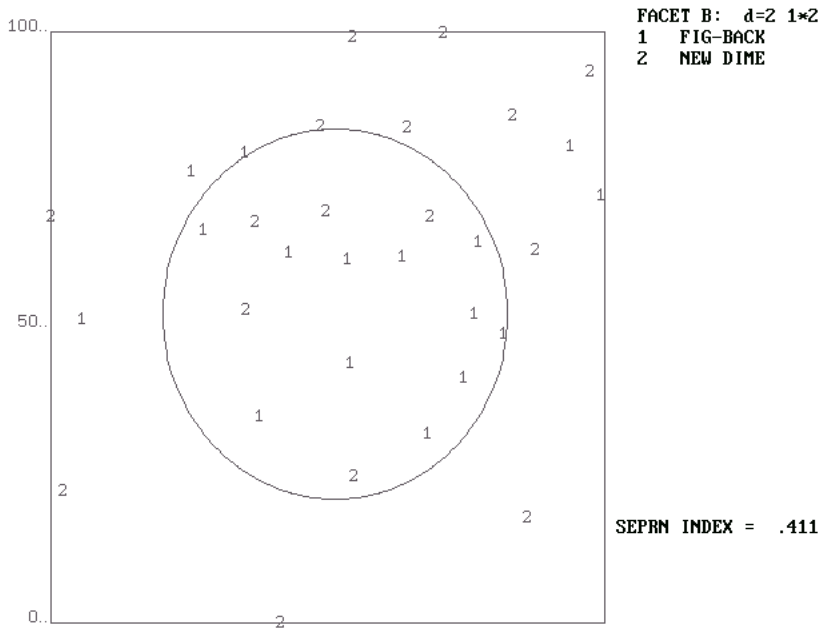


Fig. 5.2c. Creativity Space Partitioned by the Gestalt Facet: Hand Partition by an Ellipse Represents the Distinction between Figure/Ground Reassignment of Overt Elements and Invoking "New Dimension" (Importing Elements from Different Context)

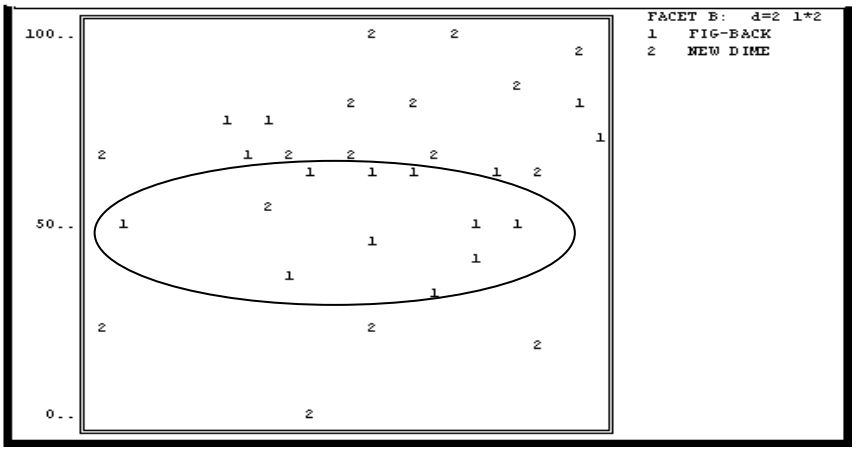


Figure 5.2c is the facet diagram produced by FSSA on which a simple curve was hand-drawn so as to best partition the space by the gestalt facet. As Fig. 5.2c shows, an elliptic curve satisfactorily separates between the two kinds of items, with the figure/ground items inside and the "new dimension" items outside the ellipse. While we do not have a computed separation index for this elliptic partition, a comparison-

by-inspection with the angular partition suggests that the degrees of fit of the two partitions to the gestalt facet are similar.
What is the meaning of an elliptic partition? In essence it is equivalent to the radial partition. In fact the elliptic pattern may be an accidental variation of the radial, resulting from a particular item sampling in a given study. As in the radial case here too we can identify a set of items that is more central—inside the closed curve—and a set that is more peripheral—outside the closed curve.

While the part of the structural hypothesis concerning the separation of the two item sets—the figure/ground and the "new dimension"-- is satisfactorily supported, the other part of the hypothesis, concerning the anticipated spatial orientation of the two regions, is not. In fact the relative location of the two regions is the opposite of the one anticipated: the "simpler" figure/ground items are in the center of the ellipse while the more complex, "new dimension" items are on the periphery.

As noted above, findings of previous studies do not agree on this issue. Indeed, the basic hypothesis that has been repeatedly confirmed in the context of intelligence testing is that the mental task complexity facet consisting of: rule recall, rule application, rule inference (inductive ability) is a radial facet with the more complex 'rule inference' at the center, and the least complex 'rule recall' at the periphery. For example, see Schlesinger and Guttman(1969); Snow et al. (1984); Shye, (1988). Moreover, Shye and Klauer (1991; 1993) having refined the mental task of rule inference into three subcategories of generalization, discrimination, and classification (argued to be ordered, respectively by increasing complexity), found that, again, the more complex the task, the closer it is to the center of the radial configuration.

Since creative problem solving has been conceptualized here as rule invention, or finding a new kind of a rule, it clearly represented a step further in its complexity than rule inference. Hence the hypothesis that creativity would occupy an even more central position in the space of mental ability than rule-inference, seemed plausible. This was indeed found by Shye and Goldzweig, 1999.

Furthermore, within creativity, the same reasoning led to the hypothesis that creativity of the "new dimension" kind would be more central than creativity of the

figure/ground kind. Surprisingly, perhaps, this was not found in the present analysis. Rather, the less complex figure/ground items are located at the center, inside the ellipse, and the “new dimension” items at the periphery.

What could possibly account for this finding? New dimension type items require playing and imagination which are often inhibited in well socialized people, except possibly with respect to materials in which they have been trained, materials with which they feel confident enough to play and raise new ideas. Wondering to far away contexts is accompanied by a sense of risk (and in some cases of stress) that many are reluctant to take. And so even if one has the potential for making new association that might lead to a creative solution, one would avoid such daring behavior. Hence, generally speaking, the relationship between ND creativity items that pertain to different materials would be weaker than the relationship between FG creativity items that pertain to different materials. This observation can account for the FG items concentrating within the ellipse and for the ND items occupying the outer circle.

The gestalt radial facet, together with the material angular facet, gives rise to the *radex theory of creativity* whose graphical representation is shown in Fig 5.5 below.

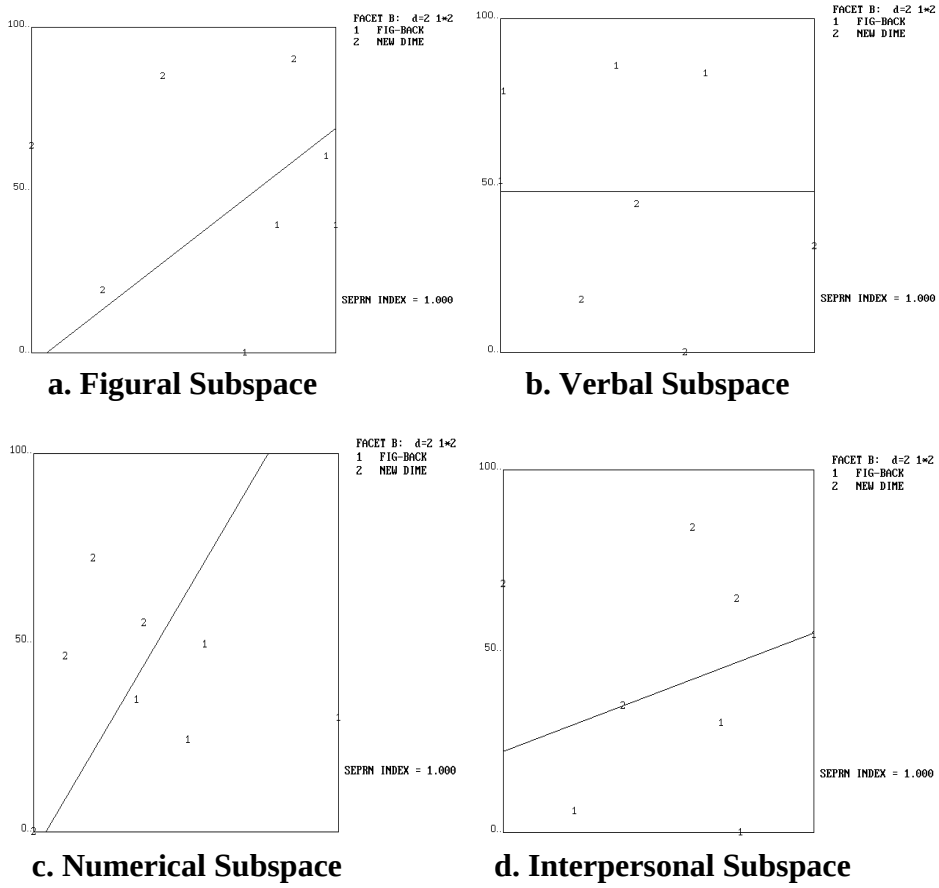
3. THE MATERIAL SUB-SPACES OF CREATIVITY

We turn now to examining the internal structure of each of the sub-spaces of creativity, defined by the material facet: The figural, the verbal, the numerical and the social. By focusing on each of them separately our purpose is twofold: First, to ascertain and obtain a clearer confirmation of the validity of the gestalt facet and second, to explore the possibility of an additional, yet unformulated, facet.

1. The Gestalt Facet within Material Subspaces

The gestalt facet within each subspace receives clear a confirmation. See Figs. 5.3.

Fig. 5.3. The Four Material Subspaces of Creativity are Perfectly Partitionable by the Gestalt Facet



a. Figural Subspace **b. Verbal Subspace**

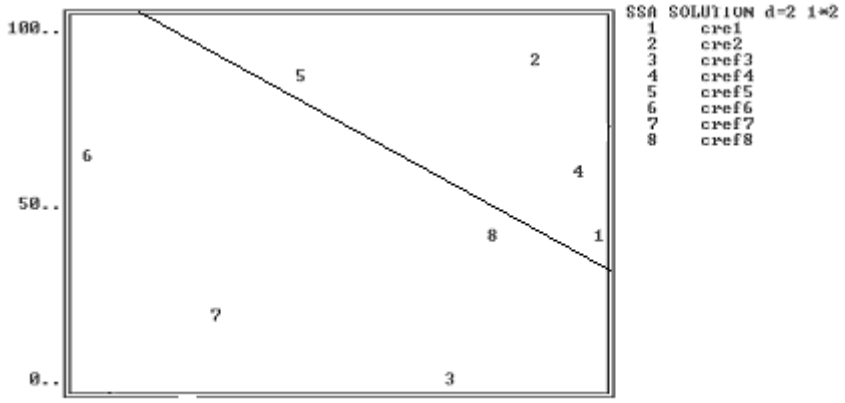
c. Numerical Subspace **d. Interpersonal Subspace**

2. Exploring New Dimensions in the Creativity Space

We shall first look at each of the four maps in **Fig. 5.3 a-d** in an attempt to discover a new facet of creativity, one that has not entered the design of this study. Then we shall try to see if there is a common theme underlying the four newly discovered distinctions. However it should be noted that even if a new facet is discovered for each of the material subspaces, a common theme to all these facets is not a necessity, and each may carry an entirely different meaning, reflecting researchers' intuitive perception of possible content variabilities within each material subspace. For obviously we have not sampled creativity items so as to cover this –or these – hitherto unformulated facet or facets.

The Figural Material Subspace. Inspecting Fig 5.3a we observe that the FG vs. ND distinction is represented by a diagonal (top-left to bottom-right) spread of the figural creativity items. To search for a new facet we focus attention on the spread of items in orthogonal (top-right to bottom-left) direction. At the top-right of the map we find items that involve very realistic physical features (color, hanging, and movement, Figural Items 5, 2 and 4 respectively. See CPST in Appendix A). At the bottom-left of the map are found items that involve symbolic or abstract notions (such as angles, Items 3 and 6, or number labels, Item 7). Hence a new facet is suggested, differentiating between concrete physical features and symbolic physical features. This inference obtains support from the fact that items occupying an intermediate position between the top and the bottom can well be considered "mixed" containing both concrete and symbolic elements. See Figural Items 1 and 8. This new distinction is shown below in Fig. 5.4a.

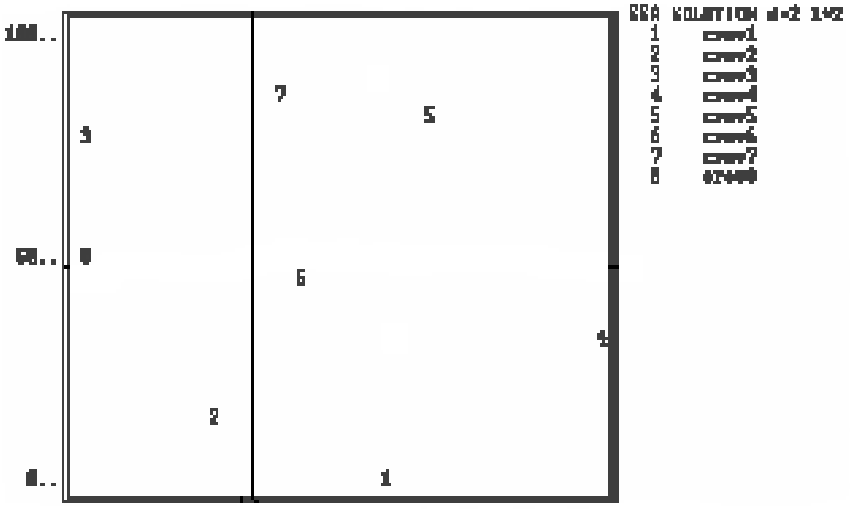
Fig. 5.4a. Figural Material: A New Facet {Concrete/Abstract} Emerges Orthogonal to the Gestalt Facet of Fig. 5.3a



The Verbal Material Subspace. To explore the possibility of an additional, new facet, we again attempt to interpret the spread of the items along a direction that is orthogonal, or approximately orthogonal, to the direction of the existing gestalt facet shown Fig 5.3b. Generally speaking we find that the right hand side of the map contains creative verbal items wherein the semantic aspect is dominant in the items and their (accepted) solutions. See verbal items 1 and 4 in CPST in Appendix. In fact, items in the right hand region carry cultural meanings and associations. On the left

hand side of the map are found creative verbal items that focus on characteristics of the words regarded as symbols. See Items 2 and 8. The other verbal items can be reasonably interpreted as comprising various combinations of semantic and symbolic features. This semantic –symbolic distinction can indeed explain this new direction rather well. This new distinction is shown below in Fig. 5.4b.

Fig. 5.4b. Verbal Material: A New Facet {Semantic/Symbolic} Emerges Orthogonal to the Gestalt Facet of Fig. 5.3b

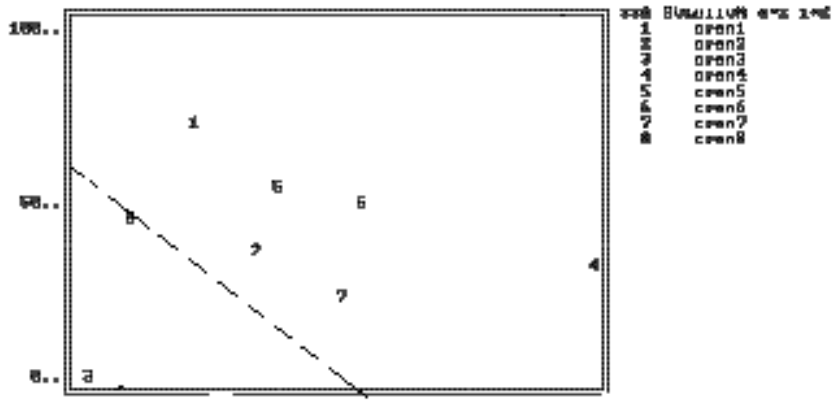


The Numerical Material Subspace. No new facet was found in the numerical creativity subspace, and all eight items essentially occupy only half of the available space in the map. In fact the spread of the test items along the direction orthogonal to that of the gestalt facet was very limited (top right region is empty) suggesting an essentially one-dimensional structure (simplex. See Fig. 5.3c). True, there is one item (3) that diverges somewhat in the orthogonal direction, an item wherein the feature of ordinality appears twice: *location* of the *largest* figure (See Item 3, Appendix A). But ordinality plays a role in the definition of the gestalt facet, while here we are looking for another, distinct classification. Attempts to contrast this item with the other numerical items by a different concept have not been successful.

Is the non existence of a new facet in the creative numerical space of these data an inherent characteristic of this space, so that no new dimension can be expected here, or is it a consequence of our item sampling? We are inclined to believe that the latter is

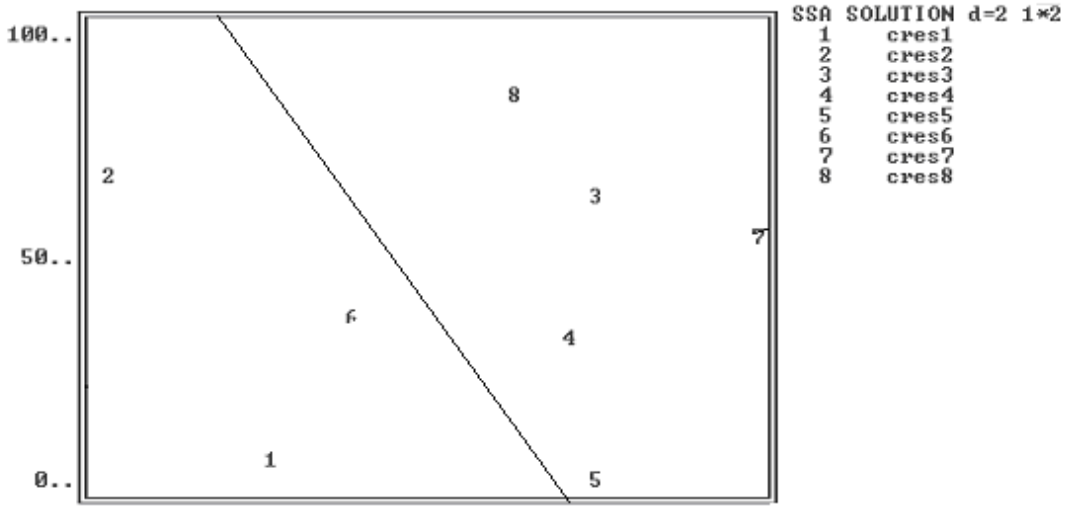
the case, and that new ideas in numerical creativity testing are likely to yield a new dimension here as well.

Fig. 5.4c. Numerical Material: No New Facet Emerges Orthogonal to the Gestalt Facet of Fig. 5.3b



The Interpersonal Material Subspace. Here the spread of items along the direction orthogonal to that of the gestalt facet is very good, suggesting that a new facet does in fact exist in these data. See Fig 5.4d. In an attempt to identify the meaning this new facet we contrasted social creativity Items 1 and 2 with Items 7 and 8 (see Appendix A). Our hunch is that the one pair of items (Items 1 and 2) involve social-institutional context and roles (formal interaction among strangers in a hotel, and dealing with the institution of the reserve army, respectively), while the latter (Items 7 and 8) focus on personal and emotional interactions (conflicting personal desires, and unexpected friendship, respectively). The other items fall in between these two extreme landmarks.

Fig. 5.4d. Interpersonal Material: A New Facet {Institutional/Personal} Social Context Emerges Orthogonal to the Gestalt Facet of Fig. 5.3d



Commonality of the New Facets. If the newly discovered facets within the material subspaces, the figural the verbal and the interpersonal were found to have a common general concept—however abstract that concept might be – that would be a major progress towards an elegant and compact theory of creativity, based on a three dimensional configuration. The three dimensions would correspond to the three facets: material, gestalt and that newly inferred generalized facet.

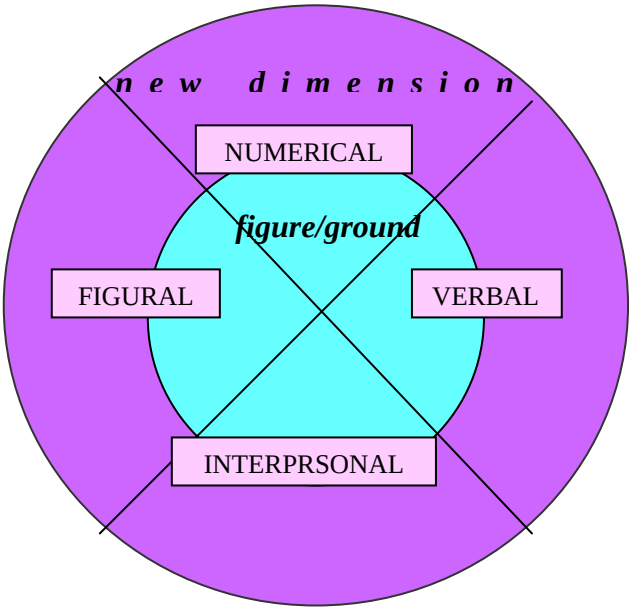
The evidence gathered in the analyses conducted above points to the possibility of such a generalized facet, one that cuts across all material subspaces. In the figural and verbal subspaces, the newly discovered differentiation seem to be highly similar-- both concern the degree of symbolization, whether high (abstract) or low (concrete). In the numerical subspace, no differentiation was empirically found, leaving the door open to suitable supplementations in the future to accommodate a preferred differentiation. In the interpersonal subspace a new sub-classification (formal-contextual vs. personal-emotional item) was suggested. At first sight, this sub-classification does not seem to easily lend itself to a conceptual abstraction analogous with that of “abstract vs.

concrete" differentiation suggested for the figural and verbal subspaces. But attempts to identify such an analogy are worthwhile. Perhaps they can be based on the observation that formal social relations represent an abstraction of concrete interpersonal relationships. On the tentative basis of this generalization we propose a 3-dimensional structure for the concept of Creativity.

4. CONCLUSION: THE CREATIVITY PIE

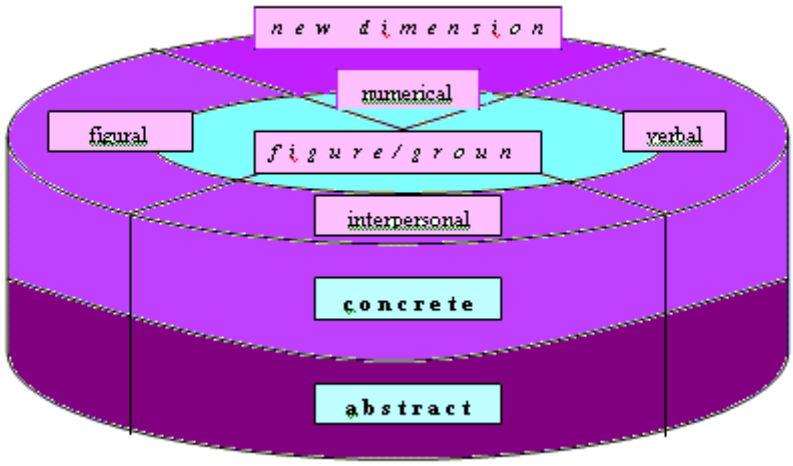
The material facet and the gestalt facet, together, yield the creativity radex, whose schematic depiction is presented in Fig. 5.5.

Fig. 5.5. The Creativity Radex: A 2-dimensional Spatial Representation of the Creativity Concept Depicting a 2-faceted Structure, the Material Facet (Angular) and the Gestalt Facet (Radial)



If we tentatively accept the additional *concrete vs. abstract* facet as a possible hypothesis for further study we obtain a depiction of creativity space as a two-layer pie as schematically shown in Fig. 5.6 below.

Fig. 5.6. The Creativity Pie: A 3-dimensional Spatial Representation of the Creativity Concept Depicting a 3-faceted Structure, the Material Facet (Angular), the Gestalt Facet (Radial), and the Absrtaction Facet (Axial)



On the basis of the inferred structure of creativity, measurement of creativity can be meaningfully made. For constructing the measurement scales for creativity we shall use Partial Order Scalogram Analysis by base Coordinates (POSAC). This is the topic of the next chapter.

CHAPTER 6

THE MEASUREMENT OF CREATIVITY

Scientific measurement requires an understanding of the range and scope of all outcomes of the specific observations that are considered possible by the scientific theory. This is why inferring the structure of a measured concept is a precondition to scientific measurement (Shye, 1985). And this is why a simple summation of scores cannot be considered scientific measurement (unless a Guttman Scale has been confirmed for the data at hand). Specifically, and considering the trait of creativity as a multidimensional concept, in any arithmetic transformations of data to what might be considered "measurement scales" we want to preserve the essential "measurement features" of the observed data. One measurement feature is order between people with respect to their degree of creativity. If initial observations indicate that Smith is definitely and in every sense more creative than Jones, we want the final measurement scales to reflect that fact. But if initially observed data shows that Smith is more creative than Jones in some senses (e.g., when it comes to verbal, numerical and interpersonal materials) but is less creative than Jones in other senses (e.g., in the figural material) then we want the measurement scales to reflect this incomparability between the two persons, too, since there is no basis for assigning weights to the different kinds of material. Practically speaking, what is required is a procedure that, given the original data, would yield the minimum number of measurement scales ("yardsticks") capable of representing the observed order relations (incomparable as well as "greater than") between all pairs of subjects participating in the tests. The theory of Multiple Scaling (Shye, 1985) develops the mathematical aspects of scientific multidimensional measurement. The procedures of Partial Order Scalogram Analysis by base Coordinates facilitated by the POSAC/LSA computer program produce a transformation of observed data to two measurement scales that aim to preserve the comparability and incomparability relationships observed between participating subjects. The two-dimensional measurement space thus obtained is the smallest capable of representing incomparability as well as comparability. (In a one

dimensional scale, such as obtained by summing up scores, all subject turn out comparable by fiat).

POSAC/LSA Computer program yields a plot of all testees, each represented by a point in a two dimensional coordinate space so that each testee gets two new score, x and y. These new scores are computed so as to optimally represent the order relationships --incomparability as well as comparability ("greater than")-- observed for all pairs of testees' profiles. (A subject's profile is the list of scores obtained by the subject on all validated test components.) The measurement-theoretical challenge in POSAC is the interpretation of the coordinates by assigning them psychologically meaningful concepts. This is done using the auxiliary programs LSA1 and LSA2 as well as by studying the program's *item diagrams* partitioned by step-curves so as to optimally separate between categories of the item in question.

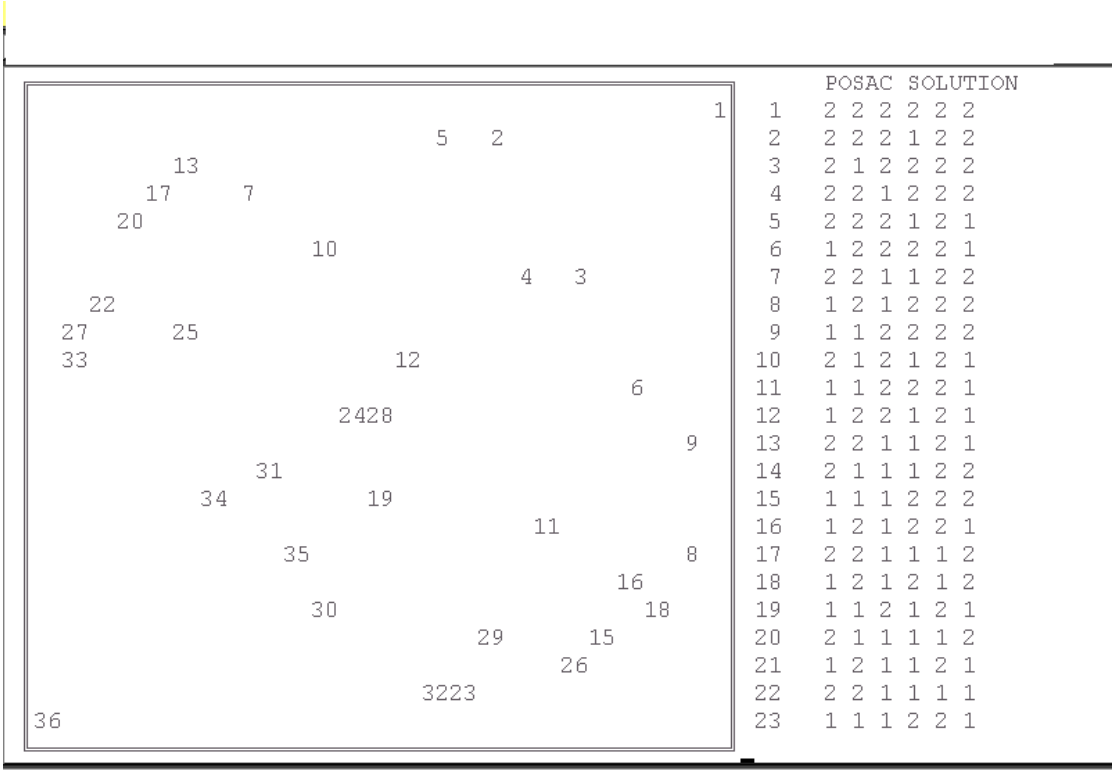
Based on the radex structure of creativity discovered (Chapter 5), six composite variables were constructed by averaging all items pertaining to each of the following kinds of creative ability:

1. Figural, (composed of all figural creativity test items);
2. Verbal, (composed of all verbal creativity test items);
3. Numerical, (composed of all numeric creativity test items);
4. Social, (composed of all social creativity test items);
5. Figure/ground, (composed of all figure/ground-type creativity test items);
6. New dimension, (composed of all new-dimension-type creativity test items).

The original scores were 1. No satisfactory solution; 2. Partial solution; and 3. Satisfactory solution. Hence each of the six composite variables could range between 1 and 3. Then we dichotomized the six variables at the score of 2.00: Those who got 2.00 or less on a composite variables, got 1 on the dichotomous composite variable, and those who got above 2.00 in the composite variable got 2 on the dichotomous composite variable.

POSAC/LSA was run on the six dichotomous composite creativity variables, to produce the coordinate measurement space (POSAC Diagram) shown in Fig.4.1.

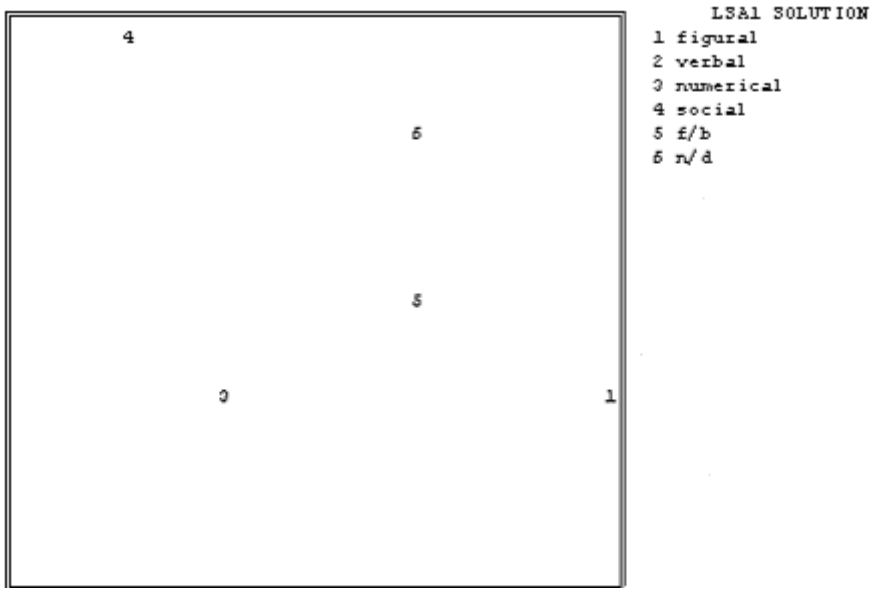
Fig 6.1. The Creativity POSAC Measurement Space
Is Based on Retaining Order-Relations Among All Testees



At the origin of the POSAC space (lower left corner, coordinates 0;0) is found the lowest profile 111111 (labeled 36) of those who did not reach a score above 2.00 on any of the six composite variables. At the upper right corner (coordinates 100;100) is found the profile 222222 (labeled 1) of those who did receive a score higher than 2.00 on all six composite variables. The POSAC program places all other profiles in between so as to reflect as faithfully as possible their comparability and incomparability relations. Thus, for example, profile 5 (=222121) is greater than profile 10 (=212121): 222121>212121. This order relation is retained by their respective coordinates (57,94)>(42,77). Similarly two incomparable profiles 10 (212121) and 12 (122121), designated 212121$122121, their coordinates would also be incomparable: (42,77)$(54,60).

Fig 6.2. The Creativity LSA Concept Space

SSA Based on The Coefficient of Structural Similarity



The second product of POSAC/LSA is the Lattice Space Analysis (LSA), essentially a smallest space analysis that utilizes the coefficient of structural similarity (rather than a statistical coefficient) for mapping variables in space. Unlike the conventional SSA, LSA is intimately linked to POSAC (Shye, 1985).

Fig 6.2 presents LSA1 map for the present case. The spatial distribution of the items indicates that Composite Variables 1 (Figural) and 4 (Interpersonal) are polar and, as hypothesized, represent the two ends of a material continuum. The other four creativity composite variables find their place in between along that continuum. However they do spread along a different, orthogonal direction. According to Multiple Scaling theory, this spatial distribution of the variables indicates that variables 4 and 1 define the overall meanings of scale-coordinate *X* and *Y*, respectively; that is, the meaning of the *X* coordinate of the creativity measurement space is dominated by social creative ability, while the meaning of the *Y* coordinate is dominated by figural creative ability. The coordinate scales are further refined by information drawn from the other variables. Again, according to multiple scaling theory, the location of variable 3 (creative numerical ability) in the LSA1 map indicates that it plays an *attenuating role*, meaning that those

"passed" it (got a score of 2) are likely to be above a certain minimum on both the *X* coordinate scale of creative social ability *and* on the *Y* coordinate scale of creative figural ability. On the other hand, Variable 6 (creative new dimension ability) functions as an *accentuator*, meaning that those who passed *it* are likely to excel either in the *X* coordinate scale of social ability or in the *Y* coordinate scale of figural ability (or in both). Finally, Variables 2 and 5 (verbal and figure/ground abilities, whose locations in the map coincide) fall roughly in the middle of the attenuating – accentuating continuum.

The conclusions drawn from LSA1 concerning the semantic structure of the coordinate scales are supported and further refined by the third product of the POSAC/LSA computer program: the item diagrams, partitioned to separate between high (2) and low (1) values in the respective item. The program produces the first four partitions from a sequence of optimal partitions with increasingly complex form (in fact, increasing number of bends in the partitioning step curve). The challenge here is to select, for each item, the one partition that best describes the role of the item in structuring the measurement space. From multiple scaling theory we know that there should be an X-polar item (an item whose partition curve has no bends—i.e. a straight line that divides the X-axis), and similarly there should be a Y-polar item. For the other items we shall choose that partition that has the minimum number of bends but whose sum of errors, or deviations, is minimal. The relevant error statistics are given by the program by a simple table that helps the researcher to reach conclusions as to the item roles:

Table 6.1. Total Deviation for Each Item in Playing Each of four Scalogram Roles (partition patterns)

ITEM	POLAR		ACC/ATT		PROMO		MODIF	
1	14.29	Y	14.29	C	14.29	Y	14.29	T
2	511.43	Y	220.00	T	171.43	X	145.71	C
3	920.00	X	134.29	T	134.29	Y	134.29	C
4	17.14	X	17.14	C	17.14	Y	17.14	C
5	662.86	Y	245.71	T	151.43	Y	102.86	T
6	445.71	X	108.57	C	102.86	X	88.57	C

Inspecting the table above we note, first that items 4 and 1 clearly play X- and Y-polar roles, respectively. For not only are their deviations low in that role, but the deviations do not decrease by assigning these items a more complex role.

Next, we observe that Item 3 is clearly an attenuating item: its total deviation is high for the polar role (920) decreases sharply (to 134) for the attenuating role and then remains at this level for the more complex roles ("promoting" and "modifying").

A similar argument leads to the conclusion that Item 6 is an accentuating item: A major decrease in the total deviation occurs as we go from the polar to the accentuating role (from 445 to 108!). But the relatively slight decreases in its total deviations beyond the accentuating role do not warrant assigning to it any of these higher order roles.

Assessing the roles played by Items 2 and 5 is more complex task. As a first approximation both play a tenuous attenuating role. By assigning the more complex role of modifying items (i.e. items whose partition line have three bends) a significant albeit not dramatic decrease in total deviation is attained.

Figs. 6.3 present our conclusions as to the role played in the scalogram by each of the six composite variables. When these pictures are superposed, the measurement space for creative problem solving is obtained. See Fig. 6.4. The measurement space is spanned by its two coordinate scales *X* and *Y,* each divided into meaningful intervals by points induced by (the ends and bends of) the six partition lines of Figs. 6.3. In light of the LSA and of the above analysis of the roles played by each composite variables the coordinate scale *X* and *Y,* that represent the most economic way of assessing creative ability, can be interpreted. The *X* coordinate represents a modified concept of interpersonal ability, where the modification is expressed by the dissection of that coordinate into intervals, "acknowledging" the roles of the other variables, esp. those of the numerical creativity and of the new-dimension creativity, in shaping that new *modified interpersonal creativity* concept. Similarly, the new concept of *modified figural creativity* is shaped and represented by the *Y* coordinate. Given the two coordinate scales, of the modified interpersonal creativity and of the modified figural

creativity, an individual can be exhaustively evaluated with respect to his or her creative solving ability (all, of course, within the confines of our conceptual framework). “Exhaustively” in that the essential measurement features of comparability in incomparability observed in the eight dimensional composite-variable data are preserved by the two coordinate scales. (The logical process of constructing a POSAC measurement space and interpreting its coordinates is detailed in Shye (1985).)

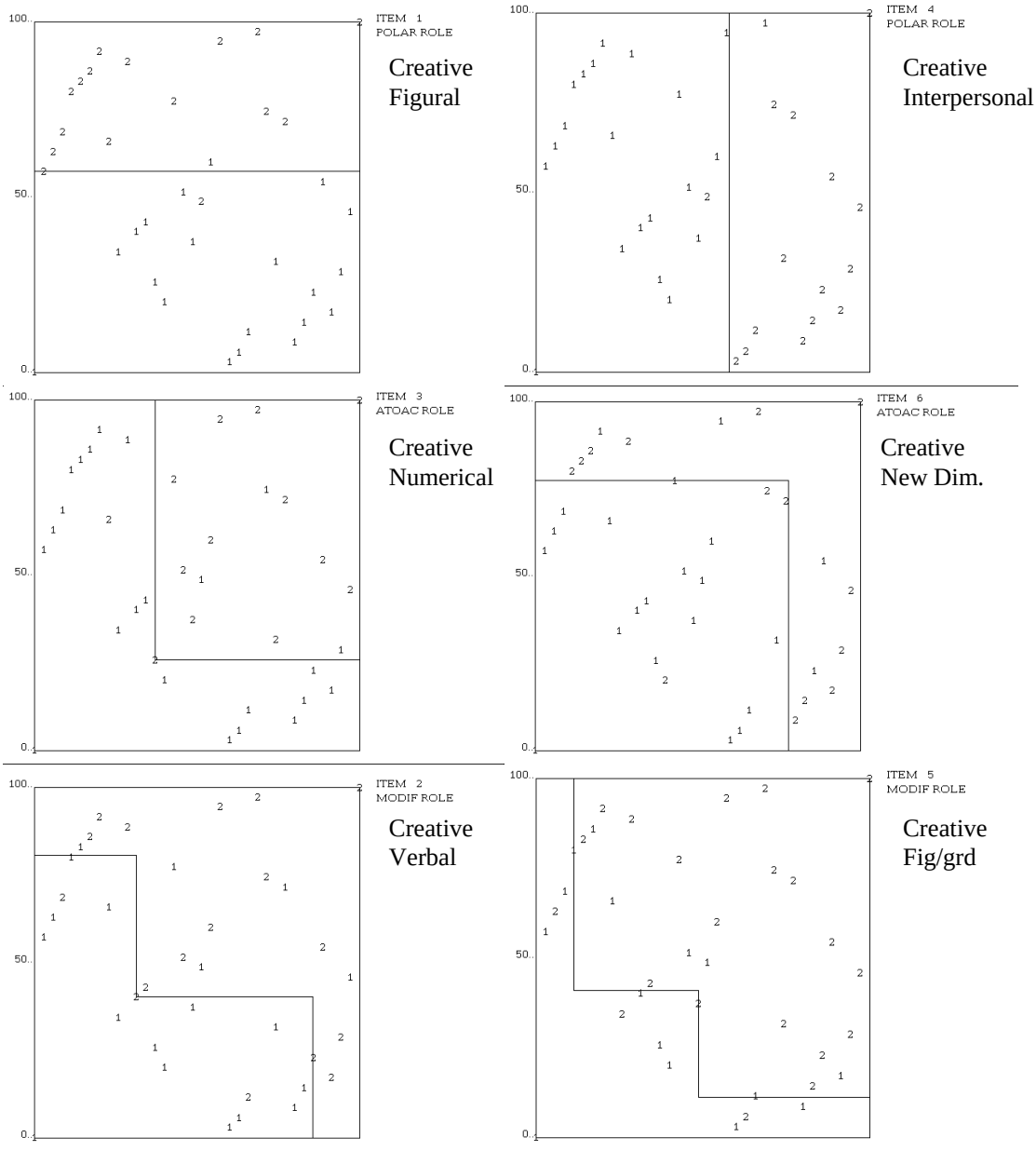
Fig. 6.3. Creativity Item-Diagrams

Showing Interpersonal (Item 1) & Figural (Item 1) abilities to be Polar;

Numerical (3) to be Attenuating;

'New Dimension' (6) Accentuating, and

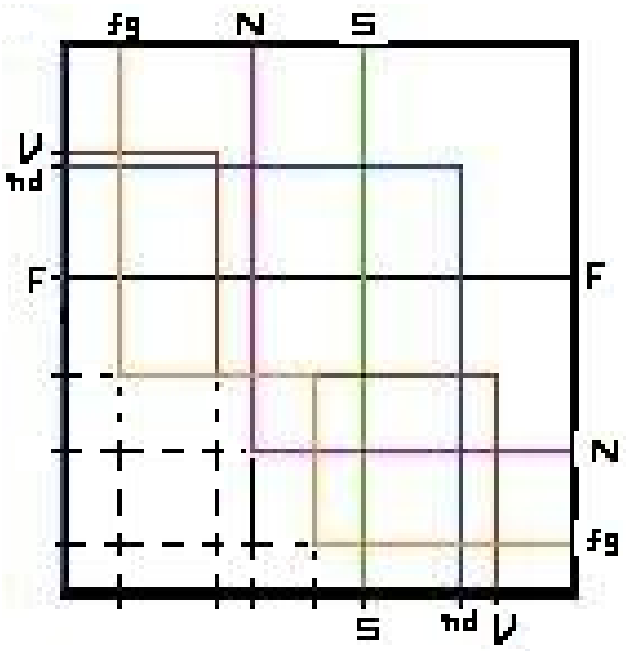
Verbal (2) and Figure/Ground (5) to be Modifying



Finally, as a two-dimensional space, the measurement space of Fig. 6.4 induces a typology on the sample of subjects and, in principle on potential testees as well: Each rectangular region in that space represents a possible profile of creative ability. Thus, the analysis by Multiple Scaling specifies, whenever appropriate, who is more creative than whom, but also what with kinds of creative abilities people are endowed.

Fig. 6.4. The Measurement Space of Creative Problem Solving: Multiple Scaling by POSAC yields Two Coordinate Scales that Preserve Order Relations Among Constituent Variables

Y-coordinate Scale: The Modified Figural Creativity



X-coordinate Scale: The Modified Interpersonal Creativity

P A R T I I I

Comparing Creativity

CPST & TTCT

CPST & SKIT

CHAPTER 7

CREATIVE PROBLEM SOLVING TEST (CPST) AND TORRANCE TESTS OF CREATIVE THINKING (TTCT): A COMPARISON

In this chapter we investigate the interrelationships between the well known TTCT and the Creative Problem Solving Test (CPST) developed in this study. We shall first look at the correlations found between the two test systems and then turn to the detailed analysis afforded by Faceted Smallest Space Analysis (SSA).

Correlations. The correlation computed between TTCT and CPST is 0.31. This figure is within the range of might have been expected. The correlation between CPST Verbal test and TTCT Verbal test is very similar—0.32. But the correlation between CPST figural test and TTCT Figural test is zero! This surprising result cannot be accounted for only by the different conceptual starting points of the two test systems but also by the way these conceptions have been translated into actual tests. Such a translation is an especially complex task since (according to our conceptual framework) the figural tests are in fact approximations (or surrogates) for tests of the mental ability of solving problems involving physical objects. Table 7.1 shows the inter-correlations among the four CPST material sub-tests and the two TTCT sub-tests.

Table 7.1. Inter-correlation among CPST and TTCT Material Sub-tests

		C P S T			
		Figural	**Verbal**	**Numerical**	**Interpersonal**
T T C T	**Figural**	**-0.01**	**0.11**	**0.08**	**0.20**
	Verbal	**0.14**	**0.32**	**0.22**	**0.33**

Examination of Table 7.1 reveals that TTCT verbal test is indeed correlated with the CPST verbal test (.32) but not less so with the CPST interpersonal test. Indeed, TTCT

verbal test contains strong social components—understanding and operating in social settings. Surprisingly, however, the TTCT figural test is the most highly correlated with CPST interpersonal test (.20) but not correlated at all with the CPST figural test! A possible explanation of these phenomena will be offered below in the structural analysis of the combined creativity space.

To complete the picture, let us look also at the subtest correlations *within* each of the test systems: The correlation between the two TTCT tests, the figural and the verbal is relatively high, .48. The magnitude of this correlation may be accounted for by the fact that the TTCT process indicators (fluency, elaboration, etc) in themselves concern general personal qualities that are not very material-specific.

The correlations between the tests of CPST are shown in Table 7.2. The correlations are, as expected, all positive, the strongest one is between the social and the verbal tests. The correlation between the two tests considered to be "symbolic" (the verbal and the numerical) is relatively high, too (.36). Generally speaking, the verbal test is the one best correlated with other tests as well as with the overall CPST score.

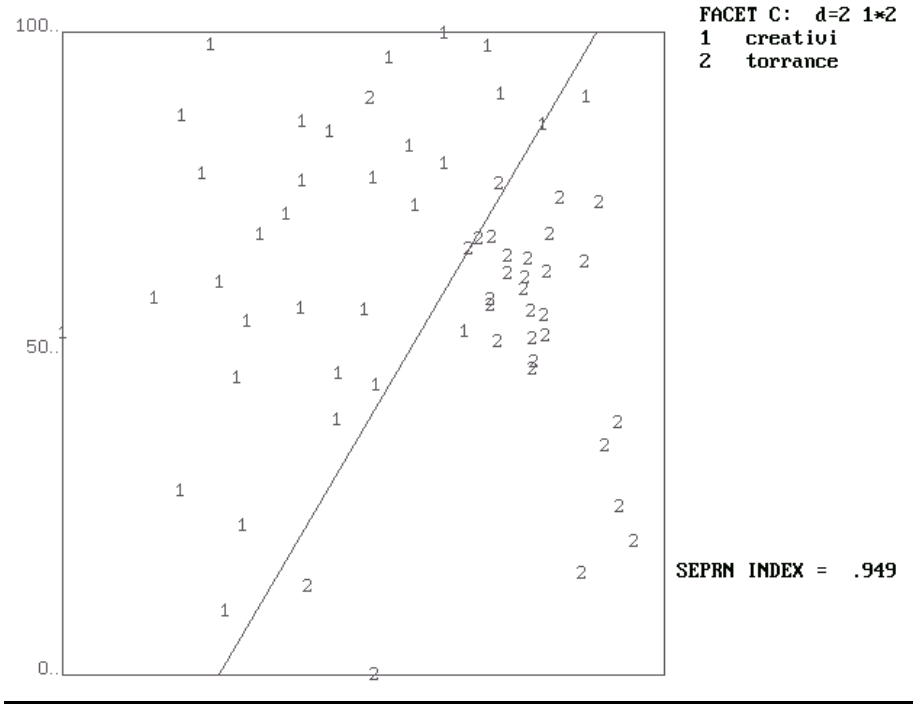
Table 7.2. Correlations Among Sub-tests of CPST

	Figural	**Verbal**	**Numerical**	**Social**	**Overall CPST**
Figural	1				
Verbal	.37	1			
Numerical	.26	.36	1		
Interpersonal	.23	.46	.26	1	
All CPST	.65	.79	.65	.69	1

For the testing of our structural hypotheses, we turn to Faceted Smallest Space Analysis of the data.

Faceted SSA. The major facet in this analysis is, of course, the one that differentiates between CPST and TTCT. Since the two testing systems originate in two different conceptions, we expect this facet to show in the SSA map that combines both test systems. See Fig. 7.1.

Fig. 7.1. Smallest Space Analysis of CPST & TTCT Test Items Faceted by Test System: The Analysis Confirms Separation Between the Two Tests Systems.



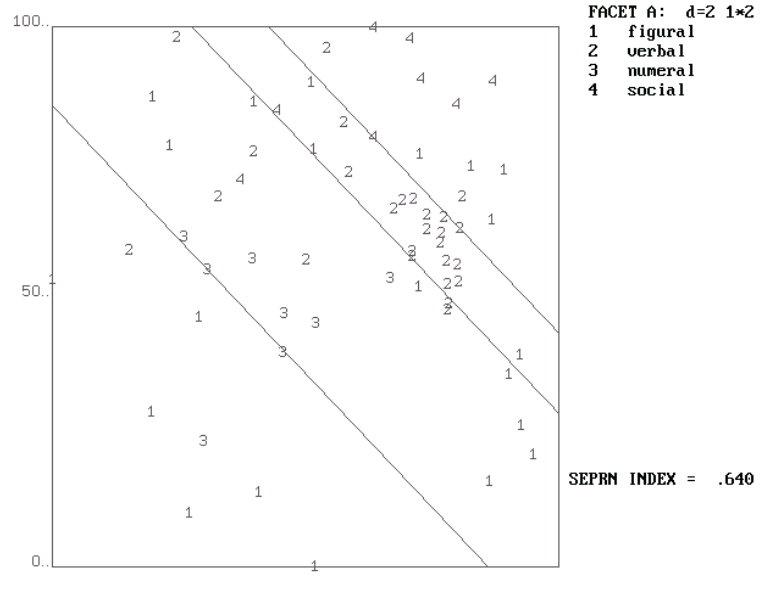
A look at Fig. 7.1 confirms our expectation. This finding suggests that the two test systems actually tap different abilities! Nevertheless the two are adjacent, i.e. they assess similar, even if not identical, mental abilities. The spatial separation in the SSA map reflects the difference between the two test systems in their definitions of creativity (problem solving through rule invention, in CPST; and a process of becoming sensitive to problems and other complex mental processes, in TTCT; see Chapter 1. If the two tests were measuring the same concept, the SSA map would have shown a thorough mixing of items from the two tests, so that no simple partitioning of the 1's and 2's were possible).

Fig. 7.1 also reveals that while our CPST items are well spread in their region of space, the TTCT items tend to concentrate at the upper part of their region. It is

instructive to attempt an interpretation of the spread of items along a (slanted) vertical axis (coinciding with the partition line shown) to discover a new facet that cuts across the CPST/TTCT differentiation: Among the few items at the bottom we find mostly figural items clearly classifiable as “new dimension” items (If we apply CPST terminology to both test systems), while at the top are found mostly interpersonal items (of CPST; TTCT has no interpersonal items). Assuming the item sampling in this study is reasonably good, this finding may indicate that new dimensional figural creativity has a unique role within the universe of creative ability.

Next we turn to investigate the relevance of the material facet for the combined CPST+TTCT creativity universe. Here we tentatively assume that the two test systems tap a wider universe of creativity, and try to identify four regions distinguished by the test material: figural, verbal, numerical and interpersonal, recognizing, of course, that the latter two are absent in TTCT. See Fig. 7.2.

Fig. 7.2. Smallest Space Analysis of CPST & TTCT Test Items Faceted by Material: The Partial Separation Exhibits Many Deviations

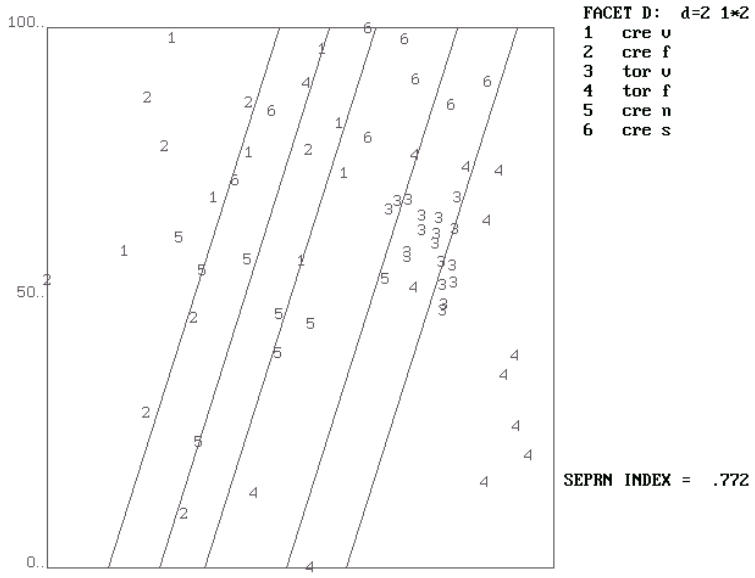


Although the separation by the material facet, across the two test systems, is quite satisfactory, overall, the top-right region is that of the interpersonal creativity; the

bottom-left region is that of the figural creativity, attesting to the presence, even in this expanded universe, of the figural-interpersonal polarity discussed earlier in the section on multiple scaling by POSAC. The symbolic kinds of material, the verbal (items marked by 2s) and the numerical (marked by 3s) find their place in between. Much in accordance with our conceptual framework, the verbal region is adjacent to the interpersonal region and the numerical region is adjacent to the figural region. All these findings provide an interesting support for the original conceptual framework in a new universe made up of very heterogeneous items, stemming from two very different definitional and procedural schemes, CPST and TTCT.

Nevertheless, the Faceted SSA map also exhibits many systematic deviations that call upon us to examine the structure of the expanded universe more closely. To do this we run SSA with a facet that combines both, the test-system facet as well as the material facet, thus distinguishing between TTCT-figural items and CPST-figural items; and distinguishing between TTCT-verbal items and CPST-verbal items. The overall separation has indeed improved, as shown in Fig. 7.3.

Fig. 7.3. Smallest Space Analysis of CPST & TTCT Test Items Faceted by Material in Each Test-System: The Technically Improved Separation Reveals a Wide Distance between the TTCT-figural and the CPST-figural sub-universes



Inspecting Fig. 7.3 several observations can be made. First, there is a clear separation between TTCT items (the two regions on the right hand side) and the CPST items (the four regions on the left hand side). This dichotomous partition (found already in Fig. 7.1 above) is further refined by the material facet *within* each test system. A surprising phenomenon emerges: the two figural tests, that of TTCT and that of CPST, are the farthest apart! This may reflect the fact that TTCT stresses visual representation and hand drawing by testees, while CPST (by its conceptual design) emphasizes abstract interpretation of physical qualities. The contrast between the two figural tests is greater than the contrast between the two verbal tests, where the mode of response, at least, is similar.

Next we note that the two verbal regions (CPST's and TTCT's) are indeed closer together and surround the CPST interpersonal creativity test region. This finding provides further support for the hypothesized affinity between interpersonal and verbal abilities, even regardless of the source, philosophy or scheme on which the test is based. This is especially true here since TTCT "verbal" items actually have a social, not just verbal, component.

Finally we note that within the CPST material regions, the order is the one observed above in Fig. 7.2: Figural, Numerical, Verbal, and Interpersonal.

The computer-partitioned map of the item diagram in Fig. 7.3 is a test of the axial structural hypothesis (namely the hypothesis that the space can be neatly partitioned into 6 regions by 5 parallel straight lines). This hypothesis is indeed supported to a certain degree (Separation Index= .77). However the results also call for an explorative analysis, in order to see whether an alternative pattern emerges.

To do this we looked at the SSA facet diagram stripped of any a priori partition model and attempted to identify regions of homogeneous contents. The result is shown in the diagram of Fig.7.4. Fig. 7.5 is a schematic representation of that diagram, constituting an interpretation of the map. Fig. 7.5 highlights the following: First, the materials classified as of "low symbolization" (in the language of Table 2.1), namely CPST-interpersonal, CPST-Figural and TTCT-figural, are circularly arranged in an outer ring reflecting the wider test-diversity in this kid of material. In the inner region are found

the “high symbolization” materials—CPST-numerical, CPST-verbal and TTCT-verbal, and perhaps significantly, an empty sub-region that would have probably contained TTCT-like numerical test-items if there were any. The phenomenon that symbolic materials tend to crowd in the center of the mental ability space has been observed before.

Fig 7.4. Smallest Space Analysis of CPST & TTCT Test Items Faceted by Material in Each Test-System: Region are Delineated by Hand to Explore for New Configuration

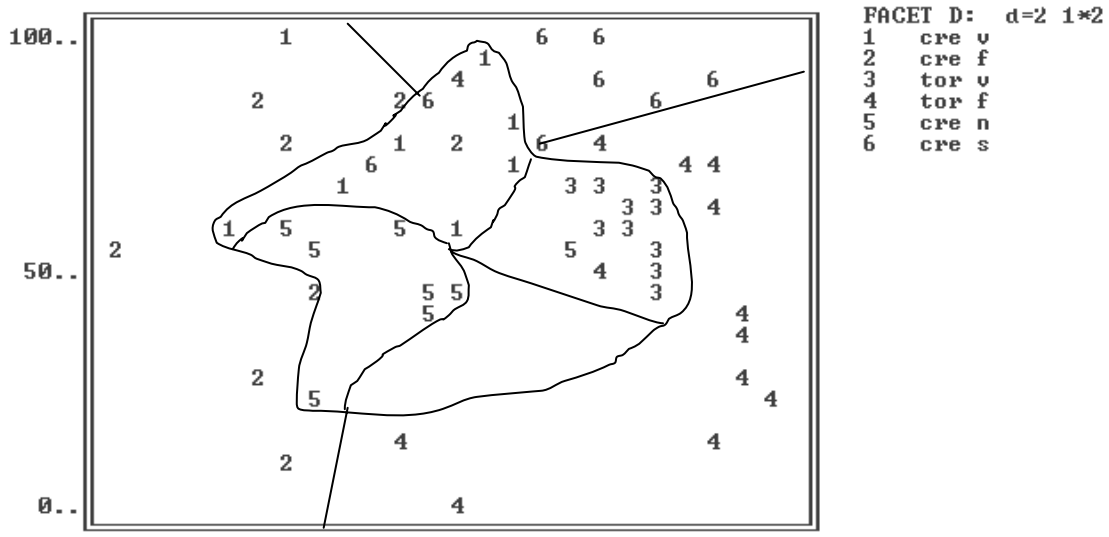
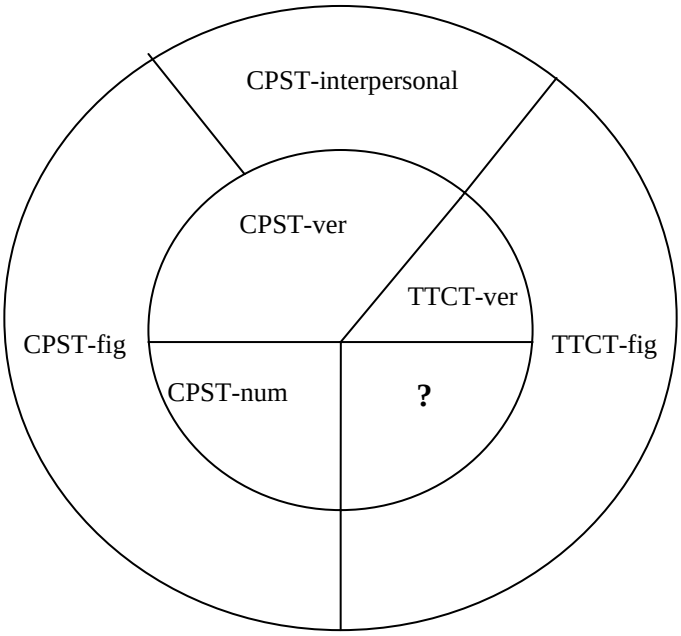


Fig 7.5. A Schematic Representation of the Space of Creative Ability Combined of TTCT and of CPST Material Tests. Concrete Materials are on the Outer Ring, Symbolic Materials are at the Center. The Verbal Material is akin to the Interpersonal and the Numerical Material is akin to the Figural Material



To conclude this chapter, the Creative Problem Solving Test (CPST), developed in this study, and Torrance's TTCT assess similar qualities—"adjacent qualities" in the language of SSA. Yet, as expected from their different rationales and definitions of creativity, the two test-systems are different—they do tap different mental abilities. A detailed examination reveals that while CPST and TTCT verbal tests are relatively close together, the figural tests of CPST and TTCT are much farther apart; in fact they are uncorrelated! Thus, despite their figural appearance, we noted that they actually measure very different qualities.

CHAPTER 8

CREATIVITY (CPST) IN RELATION TO INDUCTIVE INTELLIGENCE (SKIT)

The question of the relationship between intelligence and creativity has been discussed in Chapter 1. The general conceptual framework of this study implies that creative ability is but an extension of intelligence to more complex mental realm. In this study intelligence is represented by the relatively complex mental ability of inductive thinking, for which SKIT has been developed, i.e., the ability to find a rule from a given set of stimuli (Shye & Klauer, 1993; 1995). The understanding here is that the rule is new yet belongs to a class of rules that is generally known. In contrast, creative problem solving requires "inventing" a rule, meaning finding a rule of a new kind.

Correlations. The correlation between CPST and SKIT was found to be high: .74. This finding reflects the fact that the two abilities, the inductive and the creative, are also conceptually similar—both require finding a new rule. The difference between their definitions, it would be recalled, is that in inductive ability the rule sought is of a known type, whereas in creative ability the rule sought is of a new type. SKIT and CPST are constructed with these criteria in mind. However, whether or not a rule is in fact of a new kind for a given testee, cannot be determined with certainty, so some overlap between the two tests is possible, also accounting for the large overall correlation.

It is instructive to examine the correlations between subtests of SKIT and of CPST. Table 8.1 shows the relevant data. Unexpectedly, the figural subtests taken from both SKIT and CPST are not highly correlated: .29. In fact, CPST figural subtest has a greater correlation with SKIT numerical subtest (.39) than with SKIT figural subtest. Also, SKIT figural subtest is more highly correlated with CPST numerical subtest (.50) than with CPST figural subtest. A partial explanation for this is hinted in a previous finding where we saw that figural items in general tend to be much more diversified than items in other subtests. Further explanations could be based on detailed analysis of the figural items—e.g., to what extent they contain a significant

verbal component; or to what extent social ability can compensate for figural ability in their solution, etc.

More encouraging is the fact that the verbal subtests of the two tests, CPST and SKIT, are highly correlated, .57 (see Table 8.1), and, moreover, are more highly correlated with each other than with any of the other subtests. The same holds for the two numerical subtests whose intercorrelation is .54. Finally the two interpersonal tests are also highly correlated (.43) although their correlation with the verbal subtest (of the alternative test) is somewhat higher (.50).

Table 8.1. Inter-correlations Between CPST and SKIT Sub-tests

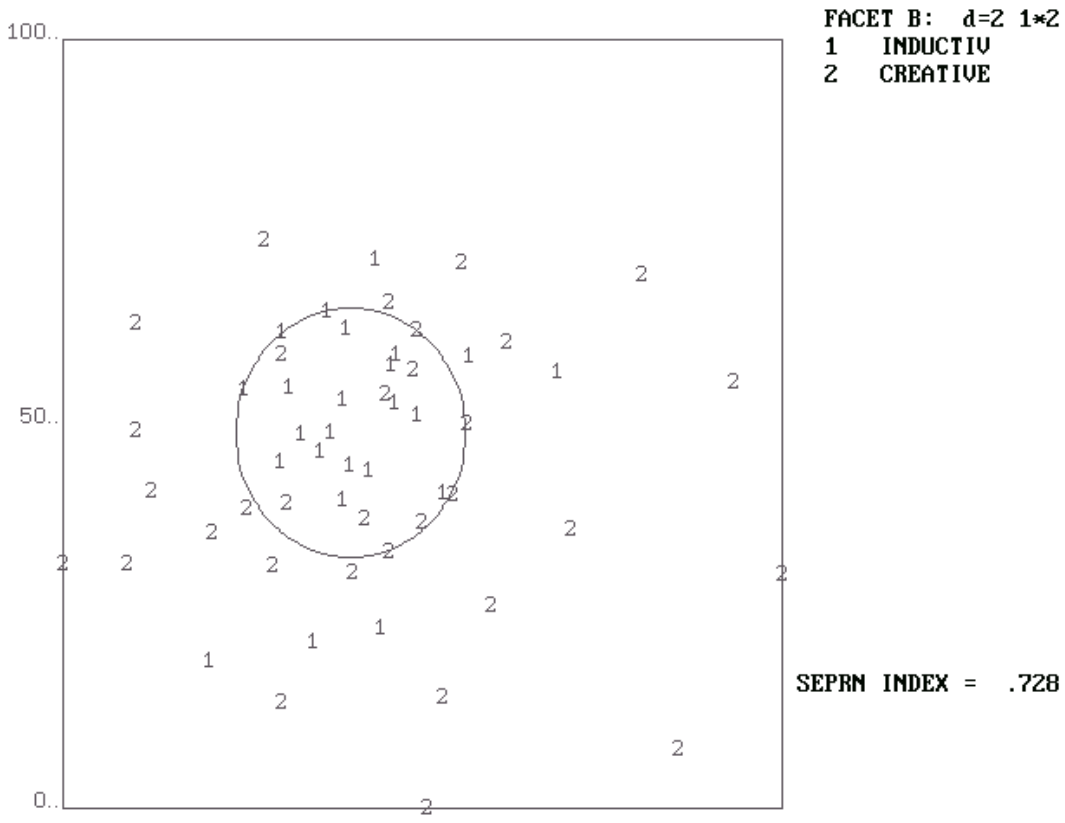
		Inductive Ability (SKIT)				
		Figural	**Verbal**	**Numerical**	**Interper.**	**SKIT**
Creative Ability (CPST)	**Figural**	**.29**	**.30**	**.37**	**.33**	**.40**
	Verbal	**.39**	**.57**	**.45**	**.50**	**.59**
	Numerical	**.50**	**.44**	**.54**	**.35**	**.57**
	Interpers.	**.34**	**.50**	**.36**	**.43**	**.50**
	CPST	**.55**	**.65**	**.62**	**.58**	**.74**

Faceted SSA. The proposed definitions of inductive and of creative abilities imply that they should be adjacent in the space of mental abilities, closer to each other than, say, creative ability and general knowledge, recall ability or the ability to following directions ("rule application"). Since these lower function tests are not included in this study, what we expect to see is two regions in the Faceted SSA map that are fairly close together. A more specific hypothesis states that the two regions would be separated by a partitioning circle, i.e., a radial configuration, and moreover, that the creativity items would be at the center.

Fig. 8.1 presents a faceted SSA of 24 SKIT composite variables and 32 creativity items. Studying this map we notice the following. First, the two tests SKIT and CPST do indeed occupy a separate region each, hence each of them probes into a different mental ability. The separation index is quite good (0.73). Second, the two regions seem to be adjacent as expected—no empty region separates them; in fact continuity

and even some mixing of the variables of the two tests are discernable. Third, the partition is indeed radial, but the creativity items are at the periphery and the inductive variables are at the center and not the other way around, as we hypothesized on the basis of the complexity argument.

Fig. 8.1. Smallest Space Analysis of CPST & SKIT Test Variables Faceted by Test System: The Analysis Confirms Separation Between the Two Tests Systems



This unexpected result echoes with what we have found earlier in Chapter 5, namely, that the new dimensional items are at the periphery and the figure/ground items are at the center. And the explanation may well be along lines similar to the ones offered there (See Section 5.2): Creativity tasks, more than inductive ones, require playing and imagination which are often inhibited in well-socialized people, except possibly with respect to materials in which they have been trained, materials with which they feel confident enough to play and raise new ideas. Wondering to less familiar contexts is accompanied by a sense of risk (and in some cases of stress) that many are reluctant

to take. And so, even if one has the potential for making new associations that might lead to a creative solution, one would avoid such a daring behavior. Hence, generally speaking, the relationship between creativity items that pertain to different materials would be weaker than the relationship between inductive-ability items that pertain to different materials. This observation can account for the inductive items concentrating within the circle and for the creativity items occupying the outer circle.

The new element invoked in the above explanation is that of social inhibition. In demonstrating intelligence, no social conflict usually arises in the tested individual and so the testing is that of mental ability uncontaminated by problems of social (un)desirability. Such ability would indeed be arranged radially with the more complex items at the center. But the demonstration of creative ability involves coping with (internalized) social ambiguities and constraints that typically drives one out to one's realm of expertise, or realm of confidence.

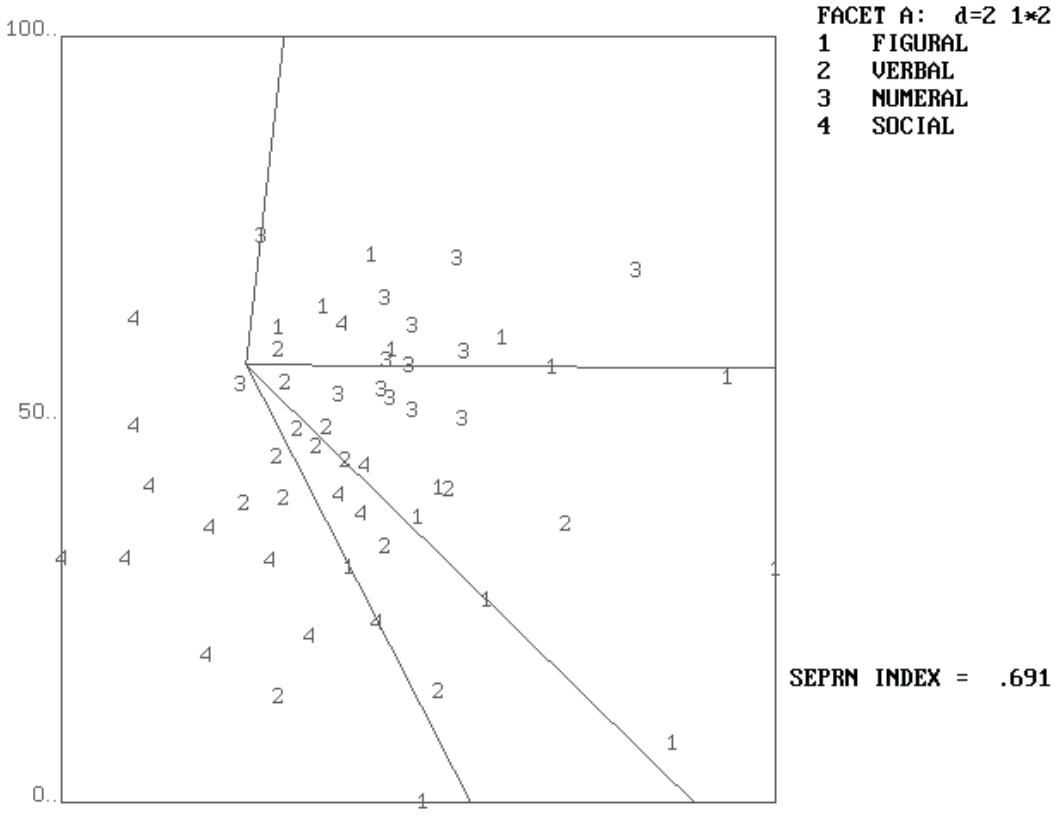
A related issue is that of accessibility to knowledge. The appearance of the creativity items at the periphery suggests that, contrary to initial expectation, they do not represent purely complex mental function (although if such pure items could be devised, they would perhaps conform to our expectation and fall at the center of the space). Rather, actual creative-problem-solving items have some special affinity to a lower mental function, namely, to accessible knowledge. The greater one's knowledge, the more one has to play with in one's search for new associations and new combinations for inventing a new rule. Wide knowledge (formally expressed in intelligence research as rule recall, and, in general, long term and short term accessible memory) constitute raw material for the creative process. Semi-organized knowledge may be especially helpful, for it lends itself to ready links yet allows also the dismantling of knowledge clusters for the purpose of re-organization and re-structuring. Since in the classical intelligence radex model, knowledge (i.e., rule recall) is found at the very periphery of the radial configuration, the problem-solving creativity items are "pulled" towards that periphery from what we originally considered their "natural" central position.

The view that creativity in a "pure" form, one that does not involve any special factual knowledge, would conform to the linear complexity hypothesis (anticipating creativity

to be at the center), while “real life” creativity, involving accessibility to considerable amounts of knowledge would be in a ring surrounding inductive ability is supported by seemingly conflicting empirical results obtained in earlier studies. In a study of inductive and creative abilities among children, where creativity tests did not rely on much prior knowledge, creativity was indeed found at the center of the radex (Shye and Goldzweig, 1999). But among university students, where tests required accessibility to some prior knowledge, inductive ability was at the center with creativity surrounding it (Yuhas, 2002).

An interesting validation of the material facet in the combined SKIT and CPST tests is afforded by Faceted SSA where the material facet is defined without regard to the test—whether inductive or creative. The analysis is shown in Fig. 8.2.

Fig. 8.2. Smallest Space Analysis of CPST & SKIT Test Variables Faceted by the Material Provides a Validation of the Material Facet across the Two Tests



In conclusion, the present chapter throws new light on the baffling question of the relationship between intelligence and creativity. In answering this question, we decomposed "intelligence" by the task-complexity facet into three components: recall ability, rule application ability, and rule inference ability. Then we simply added creativity, renamed "rule invention", as an extension, or extrapolation of the recall-application-inference continuum to obtain the wider *recall-application-inference-invention* continuum. Conceptually, each of the four abilities is distinct, a fact which is supported by empirical evidence. Yet, each ability is also adjacent to its neighboring abilities both, conceptually, as analyzed in Table 2.1, and empirically, as was found in Faceted SSA. This means that in principle, one could be high, say, in the rule inference ability but low on rule application ability.

However, in the real world, and even in the real test-world (where attempts are made to devise pure type items i.e., item that are classifiable by a priori conceptual constructs) the demonstration of a given ability may require *some* ability in the lower order ones: rule application may require some recall (e.g., recalling the rule and recalling the ad hoc data given). Rule inference may require rule application ability, (as, for example, when a testee is asked to *infer* the rule governing a given sequence of numbers and respond by *applying* the rule in order to find the number that follows the ones given). And finally rule invention, or creativity may require rule inference ability, and possibly all lower-order abilities, as well.

Thus, facet theoretical language, with its geometric imagery, seems to offer a simple yet comprehensive depiction of the relationship between creativity and intelligence. This depiction of the relationship between creativity and intelligence neatly accounts for the seemingly diverse views and findings that have been reported in the literature (Chapter1).

References

Barron, F. (1963). *Creativity and psychological health*. New York: Van Nostrand.

Barron, F. (1969). *Creative person and creative process.* New York: Holt, Rinehart & Winston.

Barron F. (1988). Putting creativity to work. In R. J. Sternberg (ed.) *The Nature of creativity*: *Contemporary psychological perspectives*. Cambridge, MA: Cambridge University Press.

Boden, M.A. (1996). What is creativity? In M.B. Boden (Ed.). *Dimensions of creativity* (pp. 75-117). Massachusetts: MIT Press.

Borg, I. & Shye, S. (1995). *Facet theory: form and content.* Thousand Oaks CA: Sage.

Cooper, E. (1991). A critique of six measures for assessing Creativity. *Journal of Creative Behavior*, 25, (3) 194-204.

Davidson, J. E. & Sternberg, R. J. (1984). The Role of Insight in intellectual giftedness, *Gifted Child Quarterly*, 28, 58-64.

Dunker, D. (1945) On problem solving. *Psychological Monographs*, 58, 270.

Eysenck, H.J. (1996). The Measurement of creativity. In M. A. Boden (Ed.), *Dimensions of Creativity* (pp. 199-142). Massachusetts: MIT Press.

Galton, F. (1869). *Hereditary genius*. New York: Macmillan.

Gardner, H. (1983). *Frames of mind: The Theory of Multiple Intelligence.* New York: Basic books.

Gardner, H. (1988). Creative life and creative works. In R. J. Sternberg (ed.) *The Nature of creativity*: *Contemporary psychological perspectives* (pp. 45-75). Cambridge, MA: Cambridge University Press.

Gardner, H. (1993). *Creating minds: An anatomy of creativity seen through the lives of Freud, Einstein, Picasso, Stravinsky, Eliot, Graham, Ghandi*. New York: Basic.

Gesell, A. (1949). *Developmental schedules*. New York: Psychological Corp.

Getzels, G. W. & Jackson, P. W. (1962). *Creativity and intelligence: explorations with gifted students*. New York: Wiley.

Ghiselin, B. (1952). *The creative process*. Mentor Books.

Gruber, H.E. (1985). From epistemic subject to unique creative person. *Archives de Psychologie*, 53 (205), 167-185.

Guilford, J. P. (1950). Creativity. *The American Psychologist,* 5 (9), 444-454.

Guilford, J. P. (1959). Traits of creativity. In H. H. Anderson (Ed.) *Creativity and its Cultivation*, (pp 142-161). Harper & Row.

Guilford, J.P. (1967). *The Nature of human Intelligence*. New York: McGraw Hill.

Guilford, J.P.& Hoffner, R. (1971). *The Analysis of Intelligence*. New York: McGraw-Hill.

Guttman L (1954) A new approach to factor analysis: the radex. In P. F. Lazarsfeld (Ed.) *Mathematical Thinking in the Social Sciences* (pp 258-348). New York: Free Press.

Guttman L (1965). A faceted definition of intelligence. In R. Eiferman (Ed*.) Studies in Psychology* (Scripta Hierosolymitana, 14, 166-181). Jerusalem: Magnes.

Guttman, L. (1968). A General nonmetric technique for finding the smallest coordinate space for configuration of point's. *Psychometrica*, 33, 469-506.

Guttman, L. (1977). What is not what in statistics. *The statistican*, 26, 81-107.

Guttman, L. (1982). What is not what in theory construction. In R. Huser, D. Mechanic & A. Haller (Eds.), *Social Structure & Behavior* (pp.331-348). New York: Academic Press,

Guttman, L. & Levy, S. (1991). Two structural laws for intelligence tests. *Intelligence*, 15, 79-103.

Martindale, C. (1989). Personality, situation and creativity. In J.A. Glover, R.R. Ronning & C.R. Reynolds (Eds.), *Handbook of Creativity* (pp.211-232). New York: Plenum Press.

Medenik, S.A. (1962). Associative basis of the creative process. *Psychological Review*, 3, 220-232.

Milgram, R.M.,& Milgram, N.A. (1976). Creative thinking and creative performance in Israeli students. *Journal of Educational Psychology*, 68, 255-259.

Nathan, M. and Guttman, R. (1984). Similarities in test scores and profiles of kibbutz twin and singletons. *Acta Geneticae Medicane et Gemellologiae*, 33, 213-218.

Nevo, B. (1972). *Ethnical and Socioeconomic Differences in some Ability Measures among Israeli Youth*. (Ph.D. thesis, The Hebrew University of Jerusalem.)

Nevo, B. (1997). *Human intelligence Vol.2*. Tel Aviv: The Open University (636-663).

Parsons, M.J. (1971). White and black and Creativity. *British Journal of Educational Studies*, 19, 5-12.

Plucker. J. A. & Renzulli, J. S. (1999). Psychometric approaches to the study of human creativity. In R. J. Sterenberg (Ed.), *Handbook of Creativity* (pp. 35-61). Cambridge Press.

Klauer, K. J. (1990). Paradigmatic teaching of inductive thinking. In H. Mandel, E. De Corte, N. Bennett & H. F. Friedrich (Eds.) *Learning and Instruction*, 2.(2) (23-45). Oxford: Pergamon.

Razik, T A. 1967. Psychometric measurement of creativity. In R. I. Mooney & T. A. Razik (Eds), *Explorations in Creativity*, 301-309. Harper & Row.

Schlesinger, I. M. & Guttman, L. (1969). Smallest space analysis of intelligence and achievement tests. *Psychological Bulletin*, 71 (2), 95-100.

Shepard, R. N. (1978). The circumplex and related topological manifolds in the study of perception. In S. Shye (Ed.), *Theory construction and data analysis in the behavioral sciences*. San Francisco: Jossey-Bass.

Shye, S. (1978a). Achievement motive: faceted definition and structural analysis. *Multivariate Behavioral Research*, 13 (3).

Shye, S. (1978b) (Ed.), *Theory construction and data analysis in the behavioral sciences*. San Francisco: Jossey-Bass.

Shye, S. (1985). *Multiple scaling: the theory and application of partial order scalogram analysis*. Amsterdam: North-Holland.

Shye, S. (1988). Inductive and deductive reasoning: a structural reanalysis of ability tests. *Journal of Applied Psychology*, 73 (2), 308-311.

Shye, S. (1991). Partial order scalogram analysis by base coordinates (POSAC/LSA): a computer program for the PC. Jerusalem: The Israel Institute of Applied Social Research.

Shye, S. (1993). Faceted smallest space analysis (FSSA): a computer program for the PC. Jerusalem: The Israel Institute of Applied Social Research.

Shye, S. (1994a). Facet theory. *The international Encyclopedia of Education* (pp. 2213-2219), Oxford: Pergamon.

Shye, S. (1994b). Partial order scalogram analysis. *The International Encyclopedia of Education*. (pp. 4308-4316). Oxford: Pergamon

Shye, S. (1994c). Smallest space analysis. *The International Encyclopedia of Education*. pp (5497-5504) Oxford: Pergamon,.

Shye, S. (1998). Facet Theory: content design and measurement in behavioral research. *European Journal of Psychological Assessment*, 14 (2), 160-171.

Shye, S. (1999). Facet Theory. *Encyclopedia of Statistical Sciences*. vol 3. New York: Wiley.

Shye, S. & Elizur, D. (1994). *Introduction to facet theory: content design and intrinsic data analysis in behavioral research. Thousand Oaks*. Calif; Sage Publication.

Shye, S. & Goldzweig, G. (1995). Creativity as an extension of intelligence: regional hypotheses and multiple scaling. In J. J. Hox, G.J. Mellenberg & P.G. Swanborn (Eds.), *Facet theory: analysis and design*. (pp 227-237). Holland, Zeist: Zetos.

Shye, S. & Goldzweig G. (1999). Creativity as an extension of intelligence: faceted definition and structural hypotheses. *Megamot, 40*, (1) 31-53. (Hebrew, with abstract in English).

Shye, S. & Klauer, K. J. (1993a). *Dimensions of inductive Ability*. (Research report containing English, German and Hebrew versions of SKIT test of Inductive ability) Jerusalem: The Israel Institute of Applied Social Research.

Shye, S. & Klauer, K. J. (1993b). Dimensions of inductive ability. *Megamot*, *35* (2-3) 179-201. (Hebrew, with abstract in English).

Simonton, D.K. (1994). *Greatness: Who make history and why*? New York: Guilford.

Simonton, D.K. (1984). *Genius, Creativity Leadership*, Cambridge University Press.

Snow, R. E., Kyllonen, P. C. & Marshalek, B. (1984). The topography of ability and learning correlarions. In R, J. Sternberg (Ed.), *Advances in the psychology of human intelligence*, 2. Hillsdale (pp.47-103). NJ: Erlbaum.

Sternberg, R. J. (1988). A three facet model of creativity. In R, J. Sternberg (Ed.), *The nature of creativity*: *contemporary psychological perspectives*. New York: Cambridge University Press.

Sternberg, R.J. (1988) (Ed.), *The nature of creativity: Contemporary psychological perspectives* (pp. 99-124). Ma: Cambridge University Press.

Sternberg, R.J. (1996). *Successful intelligence*. Simon & Schuster.

Sternberg, R. J. & Davidson, J. E. (1982). The mind of the puzzler. *Psychology Today*, 16, 37-44.

Sternberg, R. J. & Davidson, J. E. (1983). Insight in the gifted. *Educational Psychologist*, 18, 51-57.

Sternberg, R.J., & Lubart, T.I. (1991). An investment Theory of creativity and its development. *Human Development*, 34, 1-34.

Sternberg, R. J. & Lubart, T.I. (1995). *Defying the crowd: Cultivating creativity in a culture of conformity*. New York: Free Press.

Sternberg, R. J. & Lubart, T.I. (1999). The concept of creativity; prospect and paradigms. In R.J. Sterenberg (Ed.), *Handbook of Creativity* (pp. 3-12). Cambridge Press.

Sternberg, R. J. & O'hara, L. A. (1999). Creativity & Inteligence. In R.J. Sterenberg (Ed.), *Handbook of Creativity* (pp. 251-269). Cambridge Press.

Taylor, C.W. (1988). Various approaches and definitions of creativity. In R.J. Sternberg (Ed.), *The nature of creativity: Contemporary psychological perspectives* (pp. 99-124). Ma: Cambridge University Press.

Torrance, E.P. (1966). *Torrance tests of creative thinking*. Prinston, NJ: Personnel Press.

Torrance, E.P.(1974). *Torrance tests of creative thinking*. Bensenvill, Ill: Scolastic Testing Service.

Torrance, E. P. (1988). The nature of creativity as manifest in testing: In R. J. Sternberg (Ed.), *The nature of creativity*: contemporary psychological perspectives. New York: Cambridge University Press.

Torrance, E.P.(1990). *Manual for scoring and interpreting results, ttct, verbal, form a and b.* Bensenvill, Ill: Scolastic Testing Service.

Torrance, E.P.(1993). *Torrance Tests of creative thinking, verbal form b.* Bensenvill, Ill: Scolastic Testing Service.

Torrance, E.P.(1998). Norms-technical *manual for figural (Streamlined) Form a & b,* Bensenvill, Ill: Scolastic Testing Service.

Torrance, E.P., Orlow, E.B. & Safter, H.T. (1992). *Torrance tests of creative thinking*: *statistical scoring guide figural, a, b*. Bensenvill, Ill: Scolastic Testing Service.

Torrance , E. P. & Safter, H.T. (1989). The long range predictive validity of the just suppose test. *Journal of Creative Behavior*, 23, 219-223.

Vernon, P. E. (Ed.) (1970). Creativity: selected writings. Harmondsworth, Enland: Pinguin.

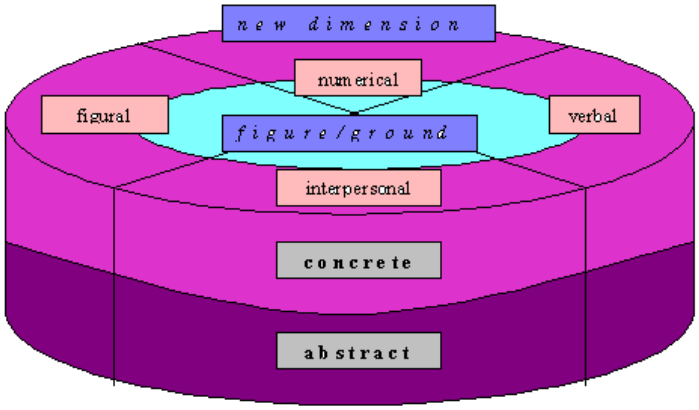
Wakefield, J. F. (1991). The outlook for creativity tests. *Journal for creative Behavior*, 25 (6), 84-193.

Wallace, G. (1926). *Art of Thought*. New York: Harcourt Brace.

Wallach, M. A. & Kogan, N. (1965). A new look at the creativity-intelligence distinction. *Journal of Personality*, 33(3), 348-369.

Weisberg, R. W. (1988). Problem solving and creativity. In R. J. Sternberg (Ed.), *The Nature* of Creativity: *contemporary psychological perspectives*. New York: Cambridge University Press.

Yuhas, I. (2002). *Who is creative*? Seminar paper presented to the psychology department, The Hebrew University, Jerusalem.



Creativity is fashioned in this study as the invention of a rule of a new kind, thus extending the bounds of intelligence. On the basis of this conception of creativity, the Creative Problem Solving Test is composed and administered to 300 respondents. Empirical results are used to structure the concept of creativity and to construct measurement scales for its assessment in individuals.

In the pictorial language of facet theory and multidimensional scaling, the study discovers three conceptual distinctions that determine the structure of creativity: the kind of material, the kind of gestalt-shift and the level of abstraction, to obtain a three-dimensional configuration, **the creativity pie**.

Creative ability in individuals can be measured using two coordinate-scales derived by the method of multiple scaling: the scale of figural creative ability and the scale of interpersonal creative ability.

The study relates the new Creative Problem Solving Test (CPST) to Torrance Test of Creative Thinking (TTCT), in order to compare conceptions of creativity; and to Shye-Klauer Inductive ability Test (SKIT) in order to reach conclusions on the relationship between intelligence and creativity.