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Analogical Reasoning:
A Review of the Literature

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The analogy, or analogical reasoning, test has played a prominent part in the history of intelligence testing. It was first introduced in the familiar a:b::c:d form by Burt (1911), who also first used the term "analogies". Woodworth and Wells (1911) at about the same time had attempted to use the analogical relations in an association test of flexibility of mental performance and "skill in handling associations." Whipple (1915) listed "analogies" in his classic Manual of Mental and Physical Tests as a measure of complex processes (tests of association, learning and memory). The analogy test was included as a subtest in the Army Alpha of the World War I period. Yerkes (1921) identified Thurstone, Otis and Bingham as responsible for development of the subtest. Subsequently, Thurstone (1919) used analogies in his pioneering work on college entrance tests; Otis (1919) included analogies as a subtest of the Otis Group Intelligence Scale; Yerkes, Bridges and Hardwick (1915) used analogies in their Point Scale; Thorndike (1919) used pictorial and geometric analogies in his Non-Verbal Intelligence Scale; Thurstone (1930) used an analogy subtest for the 1929 American Council on Education Psychological Examination; Weisenberg, Roe and McBride (1936) used an analogy test in their oft-cited study of adult intelligence; and Terman and Merrill (1937) included analogy items in the 1937 Revised Stanford-Binet Test. Spearman (1923) identified analogies as the exemplification of his theory of intelligence (later studies were to show analogies as one of the best representations of g). Finally, the analogy test emerged as a measure in its own right with development of the Miller Analogies Test (Miller, 1926), the Minnesota Psycho-

Analogies (Levine, 19) and the Minnesota Engineering Analogies Test (Dunnette, 1956). A check of the Seventh Mental Measurements Yearbook (Buros, 1972) shows that analogies are used in the following tests: A.C.E.R. General Ability Scales, Carlton Intelligence Tests, the Scholastic Aptitude Tests (SAT), the Academic Ability Tests (AAT), the School and College Ability Tests (SCAT), the Gilliland Learning Potential Examination, the Safran Culture Reduced Intelligence Test, the Schubert General Ability Battery, the Verbal Tests, and the Wesman Personnel Classification Test.

For all its success as a measure of final intelligence and as a prediction of scholastic and occupational performance, reasoning by analogy failed to attract the attention of students of psychological process. Little mention of it is made by cognitive psychologists, although one could point to Piaget's (Inhelder and Piaget, 1958) study of formal reasoning as coming very close. This review is intended to illuminate, insofar as it is possible, this little-known corner of the psychological domain. The review comes in three parts: the first traces the origins of analogy in mathematics and philosophy; the second summarizes psychological theories about analogical thinking or analogical reasoning; and the third reviews the literature on analogy as psychological test.

Analogy in Mathematics and Philosophy

"Analogy" was originally a Greek term which, according to the definition given by Aristotle, was used to signify proportionality. "For analogy is an equality of proportions, and involves at least four terms...when the second is related to the first as the fourth is to the third" (Aristotle in Metaphysics). The historical account below derives largely from Lyttkens (1952).

The theory of mathematical proportions was reputedly first propounded by Pythagoras, who in turn was supposed to have learned it from the Babylonians. Archytas, a contemporary of Plato, regarded analogy as requiring a "mean" or "middle term," that is, a middle number between two numbers so as to construct a series. He differentiated three kinds of mathematical analogy: the harmonic, the arithmetical, and the geometrical.

The harmonic analogy stemmed from the Pythagorean discovery of musical harmony and required "a given number which by the same part is as much larger than another as it is itself smaller than a third" (Lyttkens, 1952, p. 16). For example, 4 would be the harmonic "mean" of 3 and 6 because $3 + (1/3 \times 3) = 6 - (1/3 \times 6)$. The harmonic analogy would then read 3:4::4:6. (Compare this with the contemporary definition of harmonic mean, which is $H = n / \Sigma (1/x)$.)

An arithmetical analogy was constructed by finding a given number between two numbers such that the distance from the given number to the first was the same as the distance to the second, thus 3:4::4:5 or 2:4::4:6. Proportionality, therefore, in arithmetical analogy was expressed in terms of equal distances. (Again, compare this definition with the well-known contemporary definition of an arithmetic mean, $\overline{x} = \Sigma x/n$.)

Finally, the geometrical analogy was discovered in connection with the discovery of irrational numbers, which the Pythagoreans represented by geometrical figures. The theory of proportionality was used to relate irrational numbers to rational numbers, as for example, $1:\sqrt{2}::\sqrt{2}:2$. (Once more, compare with the contemporary definition of geometric mean, $G = \sqrt[n]{X_1 \times X_2 \times \ldots X_n}$.) Whereas in arithmetical analogy proportionality was founded on equal intervals or equal distances, in geometrical analogy proportionality was based on equality of ratios. In all three cases --

harmonic, arithmetical, or geometrical -- analogy was determined by a likeness of relation, that is, the analogy held if the relation between two numbers (terms) in the first pair was the same as that between the two numbers (terms) in the second pair. The original conceptualization involved the search for a "middle term" with which to construct a series of three (numbers or terms). This was later extended, specifically in geometrical analogy, to the construction of a series of four (numbers or terms). Thus by Aristotle's time, analogy meant "an equality of proportions" involving four terms such that "the second is related to the first as the fourth is to the third."

The utility of analogy, especially, geometrical analogy, in linking diverse fields such as rational and irrational numbers attracted the attention of philosophers. The writings of three in particular are worth noting: those of Plato, Aristotle and Aquinas..

Plato was the first to use the notion of analogy in philosophy, quite apart from its mathematical usage. Analogy was used by Plato to designate (a) relations between the cosmic elements, (b) similar relations between different kinds of knowledge or spheres of reality, (c) similarity in the function of two things, and (d) the nature of certain concepts as logically defined through certain real likenesses in relations. As examples: (a) in attempting to relate the two fundamental elements of earth and fire, Plato used the following analogies -- fire : air :: air : water, and, air : water :: water : earth; (b) in his theory of knowledge, Plato used the following analogies -- being : becoming :: knowledge : perception, and images : ideas :: perception : intellect; (c) in describing the function of "the good" as the cause of "being" and "intelligible knowledge," Plato used the analogy of the sun in its function as the cause of "becoming" (the sun is the source of light and therefore of vision) and of "material knowledge";

and (d) in defining "justice" Plato made use of the idea of proportional ("analogical") equality, i.e. "to give in each case 'what is naturally equal to unequals'."

Aristotle (Owens, 1951) carried Plato's use of analogy a bit further. For example: (a) In his biological classification, analogy of structure and function was used to group different genera into larger categories; (b) In his ethics (Joachim, 1951), analogy (the determination of the "mean" or a middle term in a:b::b:c) was used to define "virtue". (Arithmetical analogy defined "objective" virtue and geometrical analogy defined "subjective" virtue. "Virtue" to Aristotle was the "mean" between extremes. Objectively, virtue was equidistant from the extremes, but subjectively, it was not necessarily so, i.e., proportionality rather than equidistance was the determining factor in subjective virtue.) Similarly, analogy was used to define "justice," with arithmetical (equidistant) analogy providing the definition of justice between equals, and geometrical (proportional) analogy defining justice between unequals; (c) In his metaphysics, analogy was used by Aristotle as a principle or method of knowing. Such concepts as "form", "matter", "actuality", "potentiality", are equivocal when applied to specifics and can only be known by analogy (Owens, 1951, p. 59). In this usage, Aristotle broke new ground. Where previous usage held closely to the mathematical meaning of analogy (i.e. the analogical relation said nothing about the terms and was univocal, e.g. double is double, whether it be 120/60 or 4/2), Aristotle utilized the terms to develop the meaning of the relation (or concept, such as "form"), then used the relation to help explicate the terms.

By Aquinas' time, analogy had become an important tool in metaphysics (Lyttkens, 1952; Klubertanz, 1960). Specifically, analogy as a way of knowing was used to attack the problem of unity vs. multiplicity and the problem of the status of knowledge of God. A variety of meanings of analogy were discerned in the various analyses of Aquinas' texts. Analogy as proportionality, for example, was discussed by Aquinas in at least five different senses: proportionality as transfer (e.g. of corporeal attributes to an incorporeal God), as parallel predication (as in typical usage), as a description of similar functions (similar to one of Aristotle's usages), as a description of parallel relationships (as in Aristotle's four-term usage) and as proper proportionality between God and creatures (to explain the similarity of God and creatures) (Klubertanz, 1960). Much of this discussion appears to have little relevance to the psychological understanding of analogy or analogical reasoning.

Analogy in Psychological Theorizing

As shown earlier, analogy, or analogical reasoning, has seen wide usage in the field of intelligence testing. However, as an object of study in its own right, analogy (analogical reasoning) has not attracted much attention among psychologists. Few of the major psychological theorists have discussed analogy. The views of four -- Spearman, Thorndike, Guilford and Piaget -- are presented below. In point of time, Spearman antedates the rest, and interestingly, his theory of intelligence is best represented by the structure of analogy. His views are discussed first.

Spearman was already well-known for, among other things, his two-factor theory of intelligence when he wrote The Nature of Intelligence and the Principles of Cognition (Spearman, 1923, 1927). In this work he attempted to reduce (or in another way of speaking, to construct) a psychology of cognition to (from) "ultimate laws" ("genuine principles"). Spearman advanced three such principles:

(a) the apprehension of experience ("Any lived experience tends to evoke immediately a knowing of its characters and experiences.");

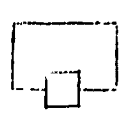
(b) the eduction of relations ("The mentally presenting of any two or more characters tends to evoke immediately a knowing of relation between them."); and

(c) the eduction of correlates ("The presenting of any character together with any relation tends to evoke immediately a knowing of the correlative character.").

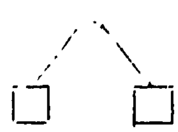
According to Spearman, all cognitive growth starts with the first principle and is capable of infinite augmentation by virtue of the second and third principles.

Of interest to this paper is the fact that Spearman used the analogy test item as a paradigm for his theory. An analogy has four elements (called "fundaments" by Spearman, following ancient usage) organized in a series format that is well-known, viz., a:b::c:d. The first Spearman principle requires the apprehension of each fundament (cognizing its character). Having apprehended two fundaments, a and b, relation p is educed according to the second Spearman principle. Likewise, fundaments c and d are apprehended and relation q (between c and d) is educed. Since relations themselves can become fundaments, a second-order relation r is educed from relations p and q. Now, if fundament d were missing and relation p were stipulated to be identical with relation q, i.e. p is the same as q, then the missing fundament d can be educed as a "correlate" according to the third Spearman principle.

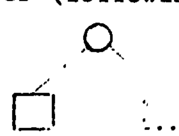
The three principles may be diagramed in this manner (following Spearman)



Principle 1



Principle 2



Principle 3

From the preceding, it can be seen that three steps (corresponding to Spearman's three principles) are necessary in the solution of an analogy test item of the form a:b::c:?

1. The subject must first apprehend (cognize) fundaments a, b, and c;
2. Next, the subject must educe relation p (which r es fundament a to fundament b);
3. The subject then introduces relation p into the second pair of fundaments and, from fundament c and relation p, educes the missing correlate, fundament d.

Spearman helpfully delineated the "range of relations" available to the educcion process. Defining "relation" as "any attribute which mediates between two or more fundaments" (p. 66), he distinguishes three broad classes: real, ideal, and rational. "Real" and "ideal" relations both have existence in the related fundaments but differ in "order" (i.e. the "real" order vs. the "ideal" order, or "reality" vs. "ideality"). In contrast, "rational" relations do not have any such existence but "only spring from particular cognitive operations upon (the fundaments)".

Relations listed by Spearman as "real" include:

(1) attribution--the relation of a character to its fundament (e.g. of redness to the thing which is red);

(2) identity--the relation of remair the same in spite of change in character;

(3) time--the relation of sequence;

(4) space--the relation of position;

(5) cause--a relation which, according to Spearman, has been subjected to too much unfruitful speculative controversy and too little genuine experimental research;

(6) objectivity--"particularly difficult relations which derive from, or are essentially superimposed upon, mental objectivity" (another area identified by Spearman as badly in need of research); and

(7) constitution--a relation of which the two fundaments are constituent parts.

"Ideal" relations as listed by Spearman include:

(1) likeness (as well as opposites);

(2) evidence--the relation of evidence (<u>not</u> cognizing relations <u>by</u> evidence: Spearman);

(3) conjunction; and

(4) intermixture (i.e., a mixture of the 10 preceding classes of relation).

These eleven types of relations are discussed by Spearman in some detail. However, no further mention of "rational" relations occurs.

The rest of Spearman's work was devoted to an elaboration of a psychology of cognition. The three principles discussed above, which are epitomized in the analogy test item, were characterized by Spearman as "qualitative", therefore requiring supplementation by "quantitative" principles. Furthermore, Spearman asserted that the "quantitative" principles were capable of physiological explanation, but not the "qualitative" principles. It was to the manifestations of the three "qualitative" principles that Spearman proposed to limit the designation of the term "intelligence".

Thorndike (Thorndike, et al., 1927) advanced a theory of "intellect" (he used this word synonymously with "intelligence") which anticipated Guilford's Structure of Intellect. Intellect, according to Thorndike, could be defined satisfactorily "only by a list of the products which it produces--the tasks which it achieves." The nature and extent of intellect as revealed in its products depended, in turn, on the "content or material operated on." Among the content favored by psychologists, Thorndike noted, were words, numbers, space-forms and pictures; content that was neglected included three-dimensional objects and "situations containing other human beings.' (Only Thorndike, of all theorists of intelligence, had a concept of "social intellig ..ce.") In constructing a measure of intellect, Thorndike would apply a wide variety of operations such as attention, retention, recall, recognition, selective and relational thinking, abstraction, generalization, organization, and inductive and deductive reasoning.

Discussing Spearman's theory under the heading "relational thinking", Thorndike agreed that "the appreciation and management of relations" was beyond doubt a very important feature of intellect. In developing his concept of "intellectual difficulty," he was guided by, among others, the following considerations: (a) that "responding to relations between objects (was) more intellectual than responding to objects"; (b) that "responding to so-called subjective or logical relations, such as likeness and difference, (was) more intellectual than responding t the so-called objective relations of space and time"; and (c) that organizing several relations to secure a certain result was more intellectual than responding to one relation at a time (Thorndike, et al., 1927, p. 63).

Despite the importance he attached to "relational thinking", Thorndike warned that perception and use of relations was not all of intellect. "In theory, analysis (thinking things into their elements), selection (choosing the suitable elements or aspects or relations), and organizing (managing many associative trends so that each is given due weight in view of the purpose of one's thought), seem to be as deserving of consideration as the perception and use of relations (in defining intellect)." Moreover, Thorndike very presciently added, "we need other valuations to decide which are the better relations or the more abstract relations, or the more essential elements, or the more sagacious selection, or the more consistent organization, or the more desirable balance.." (Thorndike, et al., 1927, p. 19-20).

Guilford's Structure of Intellect theory is well-known (Guilford, 1956, 1959, 1967, 1971). In this theory, "intellect" is mapped according to three axes or coordinates: operation, content and product. There are five operations: Cognition, Memory, Divergent Production, Convergent Production, and Evaluation. Four contents are considered: Figural, Symbolic, Semantic and Behavioral. Six products ensue: Unit, Class, Relation, System, Transformation, Implication.

According to Guilford's Structure of Intellect, analogy and analogical reasoning belong primarily to the class of cognition of relations. A completion-type analogy test would tap both cognition of relations and convergent production of relations, while a multiple-choice-type analogy test would "load" less on convergent production and more on cognition. The most common type of analogy test--word analogies--is basically cognition of semantic relations, while figure analogies would be cognition of figural relations. Guilford reports research from the Aptitudes Research Project that shows two separate factors for the eduction, respectively, of figural and conceptual (semantic) relations (Guilford and Hoepfner, 1971, p. 71). Similar hypotheses in "eduction of correlates" factors were initially supported, but subsequent data and analyses showed that these ("eduction of correlates") factors were really a confounding of convergent production and cognition factors.

Three Guilford conclusions are of importance to this survey:

1. Different content in analogy tests (e.g. word vs. figure vs.

symbol) tap different ability factors;

2. Different formats in analogy tests (e.g. completion vs. multiple choice) tap different "mixes" of cognition and convergent production factors; and
3. Analogical reasoning constitutes only a limited portion of the domain of intellect (thus disagreeing with Spearman and agreeing with Thorndike on this question).

It might be noted at this juncture that Guilford, like Thorndike before him, failed to discuss the question of the <u>types</u> of relations involved in analogy tests. Nor did Guilford, like Thorndike before him, shed any light on the process of analogical reasoning. Guilford and Thorndike might be said to be representative of American psychologists who are more concerned with <u>outcomes</u> than with processes. (This American predilection could be said to fit in with the well-known American emphasis on practicality, effectivenss, and usefulness--and American psychologists' preference for behaviorism as well.)

To find a discussion after Spearman of process in analogical reasoning, one has to turn to a non-American, the Swiss psychologist Piaget. Piaget did not discuss analogy or analogical reasoning as such, but rather the problem of proportionality (and the related problem of reciprocity), in connection with his studies of formal reasoning. (Actually, it was Inhelder who conducted experimental studies on the problem of proportionality; but it was Piaget who provided the analytical account. See Inhelder and Piaget, 1958.)

In Piaget's system, reasoning unfolds in two major stages: a concrete reasoning stage, most recognizable between the ages of 7 and 11 years; and a formal reasoning stage, which occurs between 12 and 15 years. Initially, it was thought (by Piaget) that formal reasoning was simply the culmination of the child's development in concrete operational reasoning, resulting in the emergence of a verbal or propositional logic. But Inhelder's experiments showed that propositional logic was inadequate to explain the new structures of operations found in the adolescent's thinking. Inhelder found that the notions of ratio and proportion were comparatively late acquisitions (at 13 to 15 years). A good illustration is to be found in the problem of equilibrium in the balance, wherein the child has to discover (i.e. reason to) the inverse proportional relation between weight and distance to the fulcrum. (The parallelism to the original Grecian mathematical meaning of analogy as "mean" is worth noting.)

Piaget explained the new "structures" in terms of the "four-group", or group of four transformations: I (identity), N (negation or inversion), R (reciprocal) and C (correlative). (The four transformations are also listed as: identical transformation, inversion, reciprocity, and inversion of the reciprocal or reciprocation of the inverse.) In the problem of the balance, the subject who solves the problem understands: I = to increase simultaneously the weight and distance on one of the arms; N = to reduce the distance while increasing the weight, or, diminish the weight while increasing the distance, or diminish both; R = to compensate for I by increasing both weight and distance on the other arm of the balance; and N = to cancel R in the same way N cancels I. The subject begins with a global intuition of proportionality (which corresponds to a qualitative schema of logical proportions), then passes on to more detailed logical proportions and from there to numerical proportions. This kind of proportional thinking is formally equivalent to logical reasoning.

It remained for another Englishman, Lunzer (Society for Research in Child Development, 1970), to show the application of Piaget's conceptualizations to analogical reasoning (or rather, the application of analogy test items to an explication of Piaget's theory of formal reasoning). Using verbal and number analogies (number series) constructed to investigate the role of structural complexity in adolescent reasoning, Lunzer found (1) that both verbal and number analogies required the application of formal reasoning operations; (2) that simple analogies as well as more complex ones could not be solved (by a clear majority of the group) before age 11; (3) that the most complex analogies used in the experiment could not be solved by a majority of the group until age 15; and (4) that the principal characteristic of formal reasoning was to be found in the need to elaborate second-order relations. That is, according to Lunzer, concrete reasoning ended with the determination of first-order relations, while formal reasoning required the ability to "educe" second-order relations. Piaget himself stated, "Concrete operations may be called first degree operations in that they refer to objects directly. ...(I)t is also possible to structure relations between relations, as for example in the case of proportions. ...In this sense proportions presuppose second degree operations, and the same may be said of propositional logic itself. ...(T)his notion of second degree operations...expresses the general characteristic of formal thought..." (Inhelder and Piaget, 1958, p. 254).

One cannot but remark the striking similarity of these views to those of Spearman.

Analogy in Psychological Testing

The earliest published use of analogy items in intelligence testing appeared simultaneously in the work of Burt (1911) in England and that of Woodworth and Wells (1911) in the United States. The latter reported on a subtest they called a "mixed relations" test as part of a test of logical relations (there were nine other subtests such as whole-part, action-agent, etc.). An example of their items was: "Eye--see Ear-- ". Woodworth and Wells considered the "mixed relations" subtest an indicator of "flexibility of mental performance." Apparently, the "mixed relations" form had been used by one of the authors in his study of consciousness of relations. Besides descriptive statistics, little data were reported for the "mixed relations" subtest.

It was Burt who brought the term "analogies" into the lexicon of the mental testers. The "Completing Analogies" test was devised by Burt as one of several tests of "higher mental processes", (he was especially interested in reasoning), for use in a study of children between 11½ and 13½ years of age. The item form was intended to tap thinking ("rational inference") in terms of "association by similars". According to Burt (1911), the test involved "more than mere reproduction by similarity; it involved the perception, implicit or explicit, of a relation, and the reconstruction of an analogous one by so-called 'relative suggestion'." An example of Burt's items was, "Eating : Drinking :: Hungry : .....?" (The mathematical notation was also introduced by Burt.)

Burt's findings about his "analogies" test were to be the forerunner of numerous similar findings. In his 1911 study, Burt reported a test-retest reliability coefficient of .92 for a 100-item test (immediate retest) administered to children in groups (classes), but only a coefficient of equivalence of .58 for individual administration of two halves of the test. However, the correlation between teacher-administered and psychologist-administered group test scores was .73. Validity of the test as judged against the criterion of teachers' ratings was .52 (N = 60).

Subsequent investigations replicated and supported Burt's findings. Tables 1 and 2 summarize the data from several of these early investigations. Table 1 lists the reliability findings, while Table 2 shows the validity findings.

Insert Tables 1 and 2 here

As Table 1 shows, reliability coefficients reported for analogy tests are generally high, usually in the .80's and occasionally in the .90's. One interesting observation to make about the data in Table 1 is the support for Piaget's stages of concrete reasoning (7 - 11 years) and formal reasoning (12 - 15 years) to be found in Wyatt's reliability data for 10-, 11-, 12-, and 13-year-old girls. Among the plausible explanations for the relatively lower reliabilities obtained for 10- and 11-year-olds is the possibility that formal reasoning had not as yet made its appearance in most of the children in those age groups.

Table 2 shows the validity coefficients for analogy tests obtained by several investigators. These findings may be summarized as follows: (a) Analogy test scores correlate significantly with various indicators of intelligence, such as teachers' estimates, grades, tests of intelligence and vocabulary tests; (b) Apparently, the analogy tests used in these several studies contained a significant verbal factor, as witness correlations with opposites, vocabulary, sentence completion and the like; (c) Analogy test scores correlate slightly or not at all with tests of numerical ability and tests of perceptual speed and accuracy.

It might be inferred from these data that analogy tests basically reflect a verbal factor. This conclusion appears to find support in Thurstone's classic study of primary mental abilities (Thurstone, 1938) in which he reported his analogy test as loading .60 on factor V. However, it must be noted that Thurstone identified factor V as "evidently logical in character", "deal(ing) with ideas", "characterized primarily by its reference to ideas and the meaning of words". Thurstone called the factor "verbal relations", being careful to indicate that "still another verbal factor involves verbal material in a psychologically different manner" (Thurstone, 1930, p. 84).

Thurstone's comments are reinforced by Carroll's findings (Carroll, 1942). In his factor analysis, Carroll found that the verbal analogies test loaded .54 on factor J which he identified as "reasoning ability" and "the ability to handle verbal relations." Carroll also noted that the analogy test loaded only .22 on the "verbal" factor, which was defined by vocabulary, word choice and phrase completion tests.

These (Thurstone's and Carroll's) data strongly support Guilford's interpretation of the basic factor in analogy tests as the "cognition of semantic relations", as well as Spearman's belief that the analogy test format best represented his "eduction of relations" and "eduction of correlates".

Several studies have reported on the influence of certain factors on analogy test scores. Burt (1911), the pioneer in analogy testing, examined the influence of the following factors: (a) the experimenter's (test administrator's) training (a trained psychologist's reliability coefficient, .92, was much higher than that of a teacher's, .76); (b) conditions of test administration (group testing was more reliable, .90, than individual testing, .58); (c) social status (children of superior social status were superior); and (d) sex (no difference between the sexes).

Burt also attempted to remove the language or word-knowledge factor out of his analogies test, recognizing language as an irrelevant source of variance. Words requiring specific knowledge were avoided, and problems were framed so as to indicate unequivocally to the reasoner a single unambiguous word as its solution. Thorndike (1919) resolved the language-factor problem in more straight-forward fashion by developing an analogy test with pictures. Hebb (1942) revised the Van Wagenen's (1920) analogies used in the Weisenburg, Roe and McBride (1936) study to develop a test "whose upper sensitivity is due to something else than vocabulary difficulty." Hebb's revision had the additional desirable quality of being administerable as a paper-and-pencil test ("Printed Analogies") or as an oral test ("Oral Analogies").

Bickersteth (1917) looked at the effect of practice in analogy test performance and concluded that practice did not seem to make much difference once the nature of the test was grasped by the subject.

Few studies have addressed themselves to structural factors in analogy test performance. Hamid (1925) conducted an investigation of "some factors of effectiveness in mental ("intelligence") tests", among these the "extrinsic" factors of position of the correct answer and the time-limit factor (speeded vs. non-speeded administration). He found that the total group chose the first alternative most frequently and the last (fourth) alternative least frequently, even if the correct answer was located most frequently in the fourth position and least frequently in the first. However, he also found position-preference differences between bright subjects (their preferences, except for the fourth position, conformed proportionally to the frequency of placement of the correct answer) and the less bright ("medium" and "dull") subjects, who strongly preferred (i.e. chose most frequently) the first alternative. On the matter of the time-limit factor, Hamid found that performance was apparently not affected much by whether the subject took the test under speeded (timed) vs. non-speeded (untimed) conditions. (Hamid also studied the influence of two "intrinsic" factors: "eduction" [i.e. multiple choice] and "reproduction" [i.e. completion], concluding that "eduction" produced the more reliable test.)

Ace and Dawis (in press) studied the effects of varying two properties of item structure on the item difficulty of verbal analogy items. These properties were: blank position (i.e. whether the missing word was located on the a, b, c, or d position of the analogy a:b::c:d) and position of the correct alternative (there were five response choices to an item). They found that blank position alone did not appear to be a factor, but that position of the correct alternative and the interaction of blank position and correct answer position were significant factors in determining the difficulty of analogy items, especially for easier (difficulty level > .50) items.

As the preceding citations show, very few studies have been conducted on the process by which subjects arrive at their analogies (i.e. how they educe relations and correlates) and on the structural properties of the analogy item and their bearing on subjects' response. Most of the empirical studies found in the literature have been concerned with the usefulness of analogy tests as measures of "intelligence" or as predictors of school or job success. It is apparent that analogical reasoning per se needs much more study.

Nevertheless, the analogy item has proven itself as an intelligence test item (Pintner, 1923). Analogy items have been used in the Otis (1918), the Army Alpha (Yerkes, 1921), in Burt (1924), in Spearman (1925), in the Terman Group Test (Freeman, 1950), in the Yerkes-Bridges-Hardwick Point Scale (Freeman, 1950), in the ACE Psychological Examination and in the C.E.E.B. Aptitude Tests (Mager, 1950), in the New York State Scholarship Examination (Brownstein & Weiner, 1964), in the Armed Forces Test and the Service Academy Admission Tests (Turner, 1965, 1967). Tests consisting solely of analogies include: Burts Mixed Relations Test (1911), Greys Analogy Test (El Koussy, 1934), the Miller Analogies Test (1926-), the Psycho-Analogies (Levine, 19) and the Minnesota Engineering Analogies Test (Dunnette, 1956). Of these, the Miller is best known.

The Miller Analogies Test is a particularly good example of the analogy test as a selection instrument, with reliabilities of .92 and higher for internal consistency reliability and .83 and higher for equivalent forms reliability. The Miller is a much used instrument for selection of graduate students. Average validity coefficients (against grades or comprehensive examinations) range from .35 to .55. Correlations with other mental ability tests are high (e.g. .80 against GRE Verbal, .82 against the Ohio State University Psychological Examination, and .73 against the Terman Concept Mastery Test). Doppelt (1951) found that while science majors did considerably better than non-science majors on "science" items (analogies using scientific terms), science majors also did better on "non-science" or "humanities" items, indirectly showing that specialization in a field does not necessarily confer an automatic advantage to such individuals on Miller items relating to that field. Doppelt concluded that it was the perception of relationships which was crucial to the solution--and functioning--of analogy items.

In summary, the psychometric literature is replete with evidence concerning the usefulness of the analogy item as an intelligence test item. Yet few studies can be found on the structural characteristics of the analogy item and fewer still on the process of reasoning by analogy. Certainly, if the philosophers (and some psychologists) are to be believed--that reasoning by analogy constitutes one of the most important modes of human thinking--this field bears cultivating.

References

Ace, M. E. and Dawis, R. V. The effects of two properties of item structure on item difficulty in verbal analogies. Educational and Psychological Measurement, 1973, 33, in press.

Aristotle, Metaphysics.

Baum, H., Litchfield, M. and Washburn, M. F. The results of certain standard mental tests as related to the academic record of college seniors. American Journal of Psychology, 1919, 30, 307-310.

Bickersteth, M. E. The application of mental tests to children of various ages. British Journal of Psychology, 1917, 9, 23-73.

Brownstein, S., and Weiner, M. You can win a scholarship. New York: Barron's Educational Series, Inc., 1964.

Buros, O. K. (Ed.) The Seventh Mental Measurements Yearbook. Highland Park, N. J.: Gryphon, 1972, Vol. 1.

Burt, C. Experimental tests of higher mental processes and their relation to general intelligence. Journal of Experimental Pedagogy, 1911, 1, 93-112.

Burt, C. Mental and scholastic tests. London: Staples Press, 1962.

Carothers, F. E. Psychological examinations of college students. Archives of Psychology, 121, No. 40.

Carroll, J. B. A factor analysis of verbal abilities. Psychometrika, 1941, 6, 279-308.

Colvin, S. S. Psychological tests at Brown University. School and Society, 1919, 10, 27-30.

Doppelt, J. E. Difficulty and validity of analogies items in relation to major field of study. Journal of Applied Psychology, 1951, 35, 30-33.

Dunnette, M. D. A special analogies test for the evaluation of graduate engineers. Unpublished doctoral dissertation, University of Minnesota, 1954.

El Koussy, A. H. A note on the Greys Analogy Tests. British Journal of Educational Psychology, 1934, 4, 294-295.

Freeman, F. Theory and practice of psychological testing. New York: Holt, Rinehart, Winston, 1950.

Guilford, J. P. Three faces of intellect. American Psychologist, 1959, 14, 469-479.

Guilford, J. P. The structure of intellect. Psychological Bulletin, 1956, 53, 267-293.

Guilford, J. P. The nature of human intelligence. New York: McGraw Hill, 1967.

Guilford, J. P. and Hoepfner, R. The analysis of intelligence. New York: McGraw Hill, 1971.

Hamid, S. A. Some factors of effectiveness in mental ("intelligence") tests. British Journal of Psychology, 1925, 16, 100-115.

Hebb, D. O. Verbal test material independent of special vocabulary difficulty. Journal of Educational Psychology, 1942, 33, 691-696.

Inhelder, B. and Piaget, J. The growth of logical thinking from childhood to adolescence. New York: Basic Books, 1958.

Joachim, H. H. Aristotle: The Nichomachean Ethics. Oxford: The Clarenden Press, 1951.

King, I. and M'Crory, J. L. Freshmen tests at the State University of Iowa. Journal of Educational Psychology, 1918, 9, 32-46.

Klubertanz, G. P. St. Thomas Aquinas on analogy: A textual analysis and systematic synthesis. Chicago: Loyola University Press, 1960.

Levine, A. S. A psycho-analogies test as an evaluation for psychology students. Unpublished doctoral dissertation, University of Minnesota, 1950.

Lunzer, E. A. Problems of formal reasoning in test situations. In Society for Research in Child Development, Cognitive development in children. Chicago: University of Chicago Press, 1970. Pp. 583-610.

Lyttkens, H. The analogy between God and the world. Uppsala: Almgvist and Wiksells, 1952.

Mager, N. H. How to pass college entrance tests. New York: Arco Publishing, 1950.

Miller, W. S. Miller Analogies Test. New York: Psychological Corporation, 1926-70.

Otis, A. S. An absolute point scale for the group measurement of intelligence: Part I. Journal of Educational Psychology, 1918, 9, 239-261.

Otis, A. S. Otis Group Intelligence Scale. New York: World Book, 1919.

Owens, J. The doctrine of being in the Aristotelian Metaphysics. Toronto: Pontifical Institute of Mediaeval Studies, 1951.

Pintner, R. Intelligence testing: Methods and results. New York: Henry Holt, 1923.

Pintner, R. and Renshaw, S. A standardization and weighting of two hundred analogies. Journal of Applied Psychology, 1920, 4, 263-273.

Schneck, M. R. The measurement of verbal and numerical abilities. Archives of Psychology, 1929, 107, 1-49.

Spearman, C. A measure of "intelligence". London: Methuen, 1925.

Spearman, C. The nature of intelligence and the principles of cognition. London: Macmillan, 1927.

Terman, L. M. and Merrill, M. A. Stanford-Binet Intelligence Scale, Second Revision. Boston: Houghton Mifflin, 1937.

Thorndike, E. L. A standardized group examination of intelligence independent of language. Journal of Applied Psychology, 1919, 3, 13-32.

Thorndike, E. L., Bregman, E. O., Cobb, M. V., Woodyard, E., and others. The measurement of intelligence. New York: Teachers College, Columbia University, Bureau of Publications, 1927.

Thurstone, L. L. Mental tests for college entrance. Journal of Educational Psychology, 1919, 10, 129-142.

Thurstone, L. L. The 1929 Psychological Examination. Educational Record, 1930, 11, 101-128.

Thurstone, L. L. Primary mental abilities. Chicago: University of Chicago Press, 1938.

Turner, D. R. Practice for the Armed Forces Tests. New York: Arco Publishing, 1965.

Turner, D. R. Scoring high on U. S. Service Academy admission tests. New York: Arco Publishing, 1967.

Van Wagenen, M. S. Graded opposites and analogies tests. Journal of Educational Psychology, 1920, 11, 240-263.

Weisenburg, T., Roe, A. and McBride, K. E. Adult intelligence. New York: Commonwealth Fund, 1936.

Whipple, G. M. Manual of mental and physical tests. Part II. Complex processes. Baltimore: Warwick and York, 1915.

Woodsworth, R. S. and Wells, F. L. Association tests. Psychological Monographs, 1911, 13, No. 5.

Wyatt, S. The quantitative investigation of higher mental processes. British Journal of Psychology, 1913, 6, 109-133.

Yerkes, R. M. Psychological examining in the United States Army. Memoirs Vol. XV. Washington: National Academy of Sciences, 1921.

Yerkes, R. M., Bridges, J. W. and Hardwick, R. S. A point scale for measuring mental ability. Baltimore: Warwick and York, 1915.

Table 1

Reliability of analogy test scores, by investigator

Investigator	N	Sample	n items	Type of coefficient	r_{tt}
Burt (1911)	60-75	11½-12½ year-old children	100	test-retest (same administrator)	.92
				test-retest (different administrator)	.73
Wyatt (1913)	34	11-13 year-old children	--	equivalent forms	.92
	total= 409 girls	10 year-old girls	--	equivalent forms	.35
		11 year-old girls	--	equivalent forms	.62
		12 year-old girls	--	equivalent forms	.78
		13 year-old girls	--	equivalent forms	.76
Otis (1918)	121	Grade 4-8 children	24	split-half	.73
				equivalent forms	.84
Van Wagenen (1920)	150	high school sophomores	75	equivalent forms	.83 to .89
			300	equivalent forms	.96
Schneck (1929)	210	18-21 year-old college students	--	split-half	.88

Table 2

Validity of analogy test scores, by investigator

Investigator	N	Sample	n items	Correlate	r_{xy}
Burt (1911)	60-75	11½-12½ year-old children	100	teachers' ratings of intelligence	.52
Wyatt (1913)	34	11-13 year-old children (I)	--	teachers' estimates of intelligence	.80 (I) .62 (II)
	41	10-12 year-old girls (II)		completion	.85 (I) .58 (II)
				part-whole	.67 (I) .54 (II)
				word-building	.65 (I) .54 (II)
				missing digits	.61 (I) .54 (II)
				sentence construction	.63 (I) .39 (II)
				erasure (As, Ns, Os, Ss)	.54 (I) .14 (II)
				erasure (Es, Rs)	.43 (I) .19 (II)
King & M'Crory (1918)	276	women university students (W)	--	opposites	.52 (W) .77 (M)
	268	men university students (M)		completion	.46 (W) .58 (M)
				arithmetic accuracy	.22 (W) .18 (M)
				arithmetic speed	.17 (W) .04 (M)
				logical memory	.32 (W) neg (M)
				information	.28 (W) neg (M)
				visual imagery	.20 (W) neg (M)

Table 2 (continued)

Validity of analogy test scores, by investigator

Investigator	N	Sample	n items	Correlate	r_{xy}
				total score (average)	.72 (W) .74 (M)
				university grades	.14 (W) .40 (M)
Otis (1918)	29	Grades 4-8	24	composite score	.94
				mental age (Stanford-Binet)	.97
Baum, Litchfield & Washburn (1919)	31	college seniors	--	opposites	.40
				academic rank	.39
Colvin (1919)	--	university students	10	1st semester grades	.52
Pintner & Renshaw (1920)	52	2nd-year college students	200	Otis, Form A	.79
Carothers (1921)	--	college students	--	opposites	.57
				completion	.48
Schneck (1929)	210	18-21 year-old college students	--	opposites	.72
				vocabulary	.69
				sentence completion	.45
				disarranged sentences	.29
				arithmetic reasoning	.25
				number series	.17
				equation relations	.05
				multiplication	.04
				age	-.17

Table 2 (continued)

Validity of analogy test scores, by investigator

Investigator	N	Sample	n items	Correlate	r_{xy}
Carroll (1942)	119	college students	56	morpheme recognition	.56, .55, .50
				disarranges sentences	.48
				inventive opposites	.42
				vocabulary	.42

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