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PROBLEM OF SEX DIFFERENCES IN SPACE PERCEPTION AND ASPECTS OF INTELLECTUAL FUNCTIONING

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Key measures of analytical cognitive approach are substantially related to space perception, and therefore are sex biased. Consequently a conclusion of sex differences in analytical ability based on these data appears unwarranted. The construct of analytical cognitive approach, itself, appears questionable. Space perception also appears to be a relevant variable to control in studies of sex differences in geometric and mathematical problem solving. A causal explanation of the development of sex differences in spatial perception is presented based partly on differential practice. Other causal explanations of sex differences in analytical approach are discussed and an attempt is made to accommodate them within this framework.

The thesis of this article is that sex differences in spatial perception have been neglected as an explanation of sex differences in various aspects of intellectual functioning. It seems important to draw attention to this omission since findings of sex differences in intellectual functioning are being widely cited and uncritically accepted. They are part of the data being used to make educational decisions.

The most glaring example of failure to consider the role of space perception occurs in the interpretation of the findings of sex differences in analytical approach. This nearly always boils down to differences in performance on the Rod and Frame Test (RFT), the Embedded Figures Test (EFT), or some other spatial task. While broader questions might be raised, this discussion will be limited to only those aspects of the problem that directly relate to sex differences. Other explanations of sex differences in analytical approach will be considered.

The possible role of space perception in contributing to other sex differences in intellectual functioning will be noted. Finally, in order to provide additional perspective and insight into the causality of this sex difference, an attempt will be made to sketch the main factors responsible for the development of sex differences in space perception.

Analytical Cognitive Approach

Sex differences have been repeatedly reported on some of the tasks used to measure the analytical cognitive approach (Witkin, Dyk, Faterson, Goodenough, & Karp, 1962). Women have been described as accepting the field more passively than men, being more field-dependent or global as opposed to field-independent or analytical in their style of cognition. Perceiving in an analytical way is said to involve experiencing items as discrete from their backgrounds. It reflects ability to overcome the influence of an embedding context. The two most popular measures of field dependence, EFT and RFT, involve visual space perception. While significant sex differences have been obtained with these tasks, other measures of field dependence which

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have been used, such as rotator-match brightness constancy, paper-square-match brightness constancy, or body steadiness, do not involve visual space perception and do not show sex differences of a significant amount (Witkin, Lewis, Hertzman, Machover, Meissner, & Wapner, 1954). RFT and EFT also seem to relate better to other variables (Witkin et al., 1954). Most of the research on analytical cognitive approach has used tasks of space perception.

The Spatial Character of EFT and RFT

Several studies provide documentation confirming the spatial character of these tasks. Thurstone (1944) reported correlations of .411 and .429 between two different forms of the Gottschaldt Figures Test, similar to Witkin's EFT, and the Primary Mental Abilities (PMA) Space Test. These three tests and a block design test all showed high saturations on the same Factor A, with sex loading .26 on the same factor, males achieving a superior performance.

Podell and Phillips (1959) did a cluster analysis of the results of a wide variety of tests using a small sample of 32 male subjects. The Gottschaldt Figures Test correlated .77 with Witkin's version of the EFT which in turn correlated .29 with the PMA Space Test. These three tests and others clustered together on Dimension I, which these authors call spatial decontexualization. They were unable to replicate these findings on a second small male sample.

Gardner, Jackson, and Messick (1960) performed a factor analysis of the test results of 63 female subjects. Included among the tests were RFT, EFT, Spatial Orientation, Part V of the Guilford-Zimmerman Aptitude Survey, and Thurstone's Cards Test, also a spatial test. EFT correlated .53 with the Spatial Orientation Test and .33 with the Cards Test. RFT correlated .35 with the Spatial Orientation Test and .04 with the Cards Test. All correlations but the last were significant at least at the .05 level. Significant correlations were also reported between the two Thurstone versions of the Gottschaldt Figures Test and the Witkin EFT and RFT. All five tests loaded together on the same factor. On the basis of their results, Gardner and his colleagues rejected the term field-dependence-independence in favor of field articulation. They concluded (*a*) that the results provide clear evidence that the field articulation control principle is relevant to the space factors of flexibility of closure, spatial relations, and spatial orientation, and (*b*) that distinctions among these supposedly different abilities were not apparent in their sample.

It is not possible to review the complex literature on space perception here. It should be noted, however, that while the researchers on space perception have not been in agreement about the number and names of space factors, Werdelin (1961), in a careful review of the literature, concluded that all the space factors are closely related. Michael, Guilford, Fruchter, and Zimmerman (1957) made a similar point.

Sex Differences in Space Perception

A major difficulty with the predominant use of spatial tasks in measuring analytical approach is the fact that girls and women have an inferior performance on spatial tasks even when there is no conflict with a visual field and no analysis required. This sex difference has been repeatedly found and is well known. The evidence will not be repeated here since very competent reviews are available (Anastasi, 1958; Fruchter, 1954; Sandström, 1953; Tyler, 1965; Werdelin, 1961). The difference has been reported on all spatial factors, but Werdelin (1961) concluded that it may be limited to visualization. What differences are found probably depends a great deal on how thoroughly the two groups are matched. Sex differences are not commonly found until the early school years (Maccoby, 1966). Fruchter (1954), stated that the spatial abilities mature between 11 and 15. Witkin and his co-workers (Witkin et al., 1954) reported consistent sex differences only at age 17 and after. The developmental curve of field independence closely parallels that of spatial ability (Gardner et al., 1960). An increment in the sex difference apparently occurs in adolescence.

It would seem that the empirical results of sex differences in analytic approach or field dependence might be explainable without any reference to field, without any need to infer a passive approach to the field, globality, or lack of analytical skill. The fallacy involved is similar to concluding that women are more analytical than men based on findings of superior female ability to decontexualize the red and green figures on the Isihara Color Blindness Test.

Use of a term such as analytical cognitive approach implies a generality which has by no means been established. Not only is it difficult to discriminate from the space factors, but it appears unrelated to the verbal area. Witkin and his colleagues (Witkin et al., 1962) reluctantly concluded, contrary to their hypothesis, that verbal tasks and tasks involving configurational stimuli seem to exploit different skills. Whether one considers the underlying sex difference to be in space perception or in analytical cognition is more than a matter of semantics or even of parsimony. The spatial explanation permits a logical, testable explanation of the development of this sex difference capable of subsuming other hypotheses within its frame. This will be elucidated later in this article.

Other Explanations

There have been several attempts to explain the sex differences in analytical field approach, but none considered differential spatial ability. Witkin et al. (1954) concluded that the sex differences in their findings were cultural in origin. They cited the tremendous overlapping in the male and female score distributions, and the fact that the sex differences only reached consistent significance at a time when sex role differentiation becomes more pronounced. Witkin and his co-workers (Witkin et al., 1962) have suggested, and Maccoby (1966) has elaborated, an interpretation based on the greater dependency and conformity of women. Bieri, Bradburn, and Galinsky (1958) concluded that sex differences on EFT are attributable to the superior mathematical ability of males as measured by the Scholastic Aptitude Test. These explanations may possibly be accommodated within the framework of the spatial hypothesis, as will be made clear.

OTHER ASPECTS OF INTELLECTUAL FUNCTIONING

Stable and reliable sex differences have also been reported in solving problems of geometry and mathematical reasoning (Tyler, 1965). In discussing sex differences in intelligence, there has been a tendency to lump together evidence from studies of problem solving and analytical cognitive approach, for example by Maccoby (1966). Problem-solving tasks and tests of higher mathematics often involve geometry. Thus it seems appropriate to comment on these other abilities, though separately, since the case for the role of space perception is different in each instance.

Insofar as geometry is concerned, Werdelin (1961) has established the importance of spatial perception in performance of geometric problems. He matched 143 male-female pairs in age, social class, reasoning, verbal, and number abilities. Examining the remaining sex differences in performance on a wide variety of tests, he concluded that the sex differences are attributable to inferior female skill in the space factor of visualization. He hypothesized that the sex differences do not occur on items in which visual organization is easily comprehended and which are to be manipulated as given, but on those in which the organization and reorganization aspect are exaggerated. Sex differences were less among the students schooled together, suggesting experience as a factor in producing the difference.

In the case of mathematical problem solving, Guilford, Green, and Christensen (1951) concluded that spatial visualization contributes to solution of problems, and French (1951, 1955) concluded that it promotes successful achievement in mathematics. There is, however, no direct evidence that the sex difference in mathematical problem solving is a function of failure to control for the sex difference in spatial visualization.

The closest approximation of control of the spatial visualization variable in a study of sex differences in problem solving is the study of Sweeney (1953). He found to his surprise that matching groups on the Flags Test, a test of spatial relations, proved to be as good a control for eliminating sex differences in problem solving as matching for mathematics. Had he matched for visualization rather than for spatial relations, he might have been able to eliminate the sex difference entirely. There is no intention to imply that spatial visualization is the only variable that can produce a sex difference in mathematical problem solving. Interest and motivation are important factors (Carey, 1955; Milton, 1958), and of course any study of this topic needs to control a host of factors that are not specifically related to sex. The point is that spatial visualization is a variable to be controlled. It should now be clear how the hypothesis that sex differences in mathematical ability account for sex differences in performance on the EFT (Bieri et al., 1958) might be subsumed within the spatial hypothesis. Sex differences in spatial skill may account for both.

An Illustration

An example of the gathering momentum of overgeneralization is the study by Kagan, Moss, and Sigel (1963). It has been cited as extending the evidence for global versus analytical cognitive style correlates to a broader range of tasks beyond the more directly perceptual. They concluded that males show a stronger analytic attitude than females. The only statistically significant finding of sex difference reported involved learning nonsense syllables associated with geometrical figures, a sex-biased task. On a sorting task used to measure abstraction, the categories defining the quality of abstraction were highly arbitrary, as Riley Gardner pointed out in a critique attached to the Kagan et al. (1963) paper. While boys scored higher than girls by these standards, there was no indication that the differences were statistically significant. To bolster their case, the authors cited Wechsler (1958), referring to the slight but statistically significant superiority of males on the Block Design subtest and the Picture Completion subtest of the Wechsler Adult Intelligence Scale. While it seems reasonable to say that the Block Design subtest involves analysis, it is very much a spatial task, and the Picture Completion subtest hardly seems to qualify as a test of analytical attitude at all (Cohen, 1959). Thus the findings of sex differences stem basically from spatial tasks and the evidence appears far from sufficient to warrant their general conclusion of sex differences in analytical attitude.

DIFFERENTIAL PRACTICE AS A KEY TO CAUSATION

Evidence of Learning of Spatial Perception

Stafford (1961) concluded that spatial visualization has a hereditary component which is transmitted by a recessive gene carried on the X chromosome. Thus the aptitude would appear more often in men. While the role of innate factors is not yet clear, Gibson (1953) and Santos and Murphy (1960) came to the general conclusion that perceptual learning does occur. It seems likely that the sex difference in spatial perception may be traced in part to differential learning.

Ironically enough, Witkin (1948) found that training, which was largely didactic, significantly decreased the visual dependence of a group of women on a spatial orientation task. This same task was among those which Witkin later labeled measures of analytical approach. Witkin never followed the lead of this preliminary study because the subjects reported that the correct response still seemed wrong. Witkin therefore concluded that their cognitive approach had not changed. Many scientists find a change in performance more convincing evidence than phenomenological report. However, it would be interesting to know what the subjects would have reported had they been trained to the asymptote of their ability.

The study of Elliott and McMichael (1963) is similar in that the training methods were largely didactic with even fewer actual trials of practice. They used two groups of seven subjects each. One group received only didactic training while the other group received some practice as well Only the latter group showed a significant decrease in field dependence on the RFT, but it was transient. More intensive and systematic efforts to condition the underlying behaviors may yield less ambiguous findings.

Brinkmann (1966) pointed out that ordinary school curriculum offerings are not always effective in developing spatial visualization (Brown, 1954; Mendicino, 1958; Ranucci, 1952). Like Van Voorhis (1941), he emphasized estimation and visualization in his training procedures and was able to demonstrate significant improvement in performance on a spatial perception measure. One of two matched groups of eighth-grade pupils, 13 girls and 14 boys in each group, received programmed learning for 3 weeks. The program consisted of 505 items illustrating selected concepts of geometry and materials for tactual-kinesthetic visual feedback. The program was presented during the regular period of mathematics; the control group continued with the usual instruction. Comparison of the pre-post testing scores on Form A of the Differential Aptitude, Space Relations Test, showed an increase in the experimental group significant at the .001 level. Use of the experimental program involved less reliance on the teacher. Those children who felt that the teacher taught better, possibly the more dependent ones, gained significantly less from the experimental program. This is consistent with the findings cited by Maccoby (1966) of the negative relationship between dependency and development of field independence. Brinkmann did not present data comparing the sexes on the pretesting. On the basis of the posttest raw scores, he concluded that there was no appreciable difference, and that girls can at least hold their own when provided opportunity to learn. At this age, however, spatial abilities have not fully matured, and the sex difference is probably not so great as later on. A study such as this using larger numbers of males and females of an older age would be of great value.

The data of Blade and Watson (1955) are also relevant. After the first year of engineering studies, they found average gains of nearly 1 sigma in the scores of engineering students (mostly men) on the College Entrance Examination Board Spatial Relations Tests. Gains for engineering students were significantly greater than for students in other studies, or for a group of potential students refused admission and not pursuing studies in the interim between testings. Freshmen with the 10 highest and 10 lowest scores on the spatial test greatly differed in previous course work related to spatial perception such as mechanical drawing. There were even greater differences in the frequency of jobs and hobbies of a mechanical or technical nature, which of course involve much spatial work. The relationship of such courses, hobbies, and jobs to conventional masculine role expectations should be obvious. Considering the large gains accomplished as an incidental by-product of the engineering curriculum, it may be inferred that there were many males far from the asymptote of their ability in spatial perception. It may also be inferred that the gap in a group of females would be much greater.

Differential Practice

Because of the unknowns involved in assuming what is relevant activity in increasing spatial skill, it is difficult to know whether the sexes do in fact receive differential practice. It must be remembered, however, that even during the ages of greatest sex difference, the score distributions greatly overlap, and the sex difference is often slight. It may be that even moderate overall differences in practice would be sufficient to create this effect. While experimental studies will be needed to verify this hypothesis, it is interesting to note the number of plausibly spatial activities that are sex-typed.

As Witkin and his co-workers (Witkin et al., 1954) pointed out, the increased disparity at about age 17 in field independence, and presumably performance on spatial tasks, occurs at a time of increasing sex-role differentiation. Very few girls are found in the high school classes of mechanical drawing, analytical geometry, and shop. Spare-time activities of tinkering with the car, sports, model building, driving a car, direction finding, and map reading are sex-typed and might also be sources of differential practice. When one considers the number of hours an interested boy may spend in such activities, it is easy to see how sex differences could develop. During most adult years, the academic, vocational, and avocational differences between the sexes as a whole are at least as great.

Even before the adolescent sex role divergence, there are probably relevant differences. Boys as a group spend more time in aiming activities and games, model construction, building with blocks and later with other materials. It seems very likely that these activities are involved in the development of spatial skills. The causal mix of innate, cultural, and learned factors probably varies from person to person, but the Blade and Watson (1955) and Brinkmann (1966) findings indicate that it is unwise to assume that all children normally have the experiences which will fully develop their spatial skills.

Differential learning by virtue of sex-typed activities is consistent with the findings cited by Maccoby (1966) that cross-sex typing is associated with optimal intellectual development in women. It is also consistent with the substantial amount of evidence which she cited showing a correlation, but not necessarily a causal relationship, between less analytical skill and dependency and conformity. Independent, nonconforming women would be more likely to pursue activities contrary to cultural sex-role expectations. In natural situations, several factors tend to be present together: dependency, fearfulness, less exploration, increased time with the mother, increased verbal skill, decreased spatial skill, and, for girls, conventional sex typing. For this reason, experimental approaches appear most likely to provide clarification.

Inhelder's View

Inhelder's view (Tanner & Inhelder, 1958) appears to be consonant with the thesis developed in this essay. She pointed out that while boys and girls of the same age do not show a difference in logical functioning, they do show a difference in formation of spatial representation, that is the transformation and development of geometric solids. This might serve as a preadaptation or prerequisite for later development. A slight difference in young children might thus take on greater importance with age and be increased by differential experiences. Inhelder reported that children with richer possibilities of manipulation and visual tactile exploration have better spatial representation. In her opinion, the mental image in its spatial form is originally the interiorization of the movements of exploration. Boys, at least by preschool age, show more muscular reactivity, that is, restless, vigorous overt activity, than girls (Anastasi, 1958). It appears likely that this extra activity includes a differential in movements of exploration.

Other Factors

While differential learning is regarded a very important factor, other factors may well be ordinarily involved in the causal chain of events. The possible roles of inheritance, conformity, and cross-sex typing have already been mentioned. In her discussion of the development of sex differences in intellectual functioning, Maccoby (1966) has discounted a great variety of explanations as insufficient. Each is indeed insufficient by itself, but she has erred in trying to place too much weight on any one argument.

For example, girls as a group are more verbally precocious than boys. Boys are genetically larger and stronger, and they are more active than girls (Anastasi, 1958). The girls talk somewhat earlier than boys, but even more important is their superior articulation. At 24 months McCarthy (1943) found that 78% of a girl's speech was comprehensible compared to only 49% of a boy's speech. The boys didn't entirely catch up until age 4. Satisfying needs by use of social communication mediated by words is a prominent early alternative for girls. The boys, unable to communicate so effectively, may use their superior musculature to get what they want. Less able to control and be controlled by verbal means, the stage could already be set for sex differentials in active exploration and problem solution by action rather than words. Dependency could grow out of the verbal, social bent, and could also increase this trend for both sexes.

The twig having been bent to reliance on a verbal, socially mediated approach to problems, spatial skills may not be exercised and developed in girls. As already outlined, this trend would be supported and increased by the cultural sex-typing of activities. McCall (1953) made a comparative factor study of the scores of 451 eighth-grade pupils on 31 subtests covering verbal, number, and space factors. He found that on tasks of space perception the girls used their verbal ability while the boys did not. The girls, as is consistent with previous findings (Tyler, 1965), were superior to boys in verbal ability. At this age, boys showed averagely well-developed verbal, number, and space abilities while girls excelled only in verbal ability, scoring below boys on the other two factors. McCall hypothesized that girls excel in verbal ability in early years, but that boys tend to catch up in school. Boys by their versatility then begin to excel girls.

A corollary for boys of the bent twig hypothesis is that action, nonverbal approaches may more easily become fixed, with the result that verbal, socially-mediated behavior fails to develop adequately. A full exposition of the evidence for this corollary is beyond the scope of this paper. Suffice it to note that the greater frequency of such an outcome in males is consistent with the greater frequency of aggressive behavior problems in boys and men, less interest in people, less dependency, less verbal fluency, and more problems in speech and reading (Anastasi, 1958; Tyler, 1965).

IMPLICATIONS AND CONCLUSIONS

Key measures of analytical cognitive approach are substantially related to space perception, and are therefore sex biased. Consequently a conclusion of sex differences in analytical ability based on these data appears unwarranted. Controls for differential spatial skill are needed in these studies and in studies of sex differences in geometric and mathematical problem solving. The question of the degree to which spatial skill can be learned has a potential significance beyond explaining results of studies in analytical cognitive approach. To the extent to which it is a factor in more complex mental functions, the way may be opened for improved remedial education.

Although the main focus of this article has been on sex differences, the evidence considered and the arguments developed tend to cast doubt on the adequacy of the construct of analytical cognitive approach. It should be noted that only that portion of the research of Witkin and his colleagues that deals with spatial measures, sex differences, and sex-typed personality differences is subject to the criticisms brought out in this article. Witkin's early research is not so expansive in its conclusions. The path of increasing overgeneralization may be traced in the terms used. The phenomenon which was described as visual independence in 1948 (Witkin, 1948), became field independence in 1954 (Witkin et al., 1954), analytical cognitive approach in 1962 (Witkin et al., 1962), and analytical ability in 1966 (Maccoby, 1966).

To summarize the main points of the critique: (*a*) Key measures of this construct do not appear differentiable from the spatial factors; (*b*) the term analytical consequently implies an unwarranted generality, especially since the construct appears unrelated to the verbal area; (*c*) the link between sex, sex roles, and spatial skill could account for a considerable part of the relationship between personality variables and performance on the perceptual tasks. It could also account for the fact that such correlations are higher with the spatial measures (Witkin et al., 1954). The impressive stability of the field independence measures (Witkin et al., 1954) could occur because they are related to sex-typing which itself is very stable.

Perhaps this latter point, (*c*), bears further explication. If skill on spatial tasks is learned to an important extent, and if the opportunities for learning are sex-typed, then feminine males would be less likely to engage in male sex-typed activities which develop spatial skills. Thus, generally speaking, male sex-typing would promote field independence; female sex-typing would promote field dependence. Individuals low in analytical field approach do in fact show characteristics more typical of women than men. These include less achievement motivation, more dependency, less aggressiveness, more interest in people, and poorer performance on the Block Design subtest of the Wechsler tests than on the Vocabulary subtest (Witkin et al., 1962). It appears highly likely that these relationships are mediated by sex-typed spatial learning, and would be greatly reduced by controlling for spatial ability or, as Blade and Watson (1955) prefer to say, achievement in spatial perception.

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