INTELLIGENCE 10, 141–151 (1986)

On the Relation between Spatial Ability and Field Dependence*

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Field dependence and spatial ability are widely thought of as distinct psychological dimensions. We sought to evaluate the alternative hypothesis that these are, in fact, different labels for a common underlying dimension. A sample of 60 subjects was selected on the basis of scores on a test of spatial ability. These subjects completed two tests of field dependence—the Embedded Figures Test and the Rod-and-Frame Test—and two tests of spatial ability—the Spatial Relations subtests of the Multiple Aptitude Test and the Blocks Design subtest of the Wechsler Adult Intelligence Scale (WAIS). These particular tests were selected because of (1) their prevalent use in the literature and (2) their provision of paper-and-pencil and manipulative measures of each trait. Using Jöreskog's (1970) method for the analysis of covariance matrices (LISREL–V), we estimated the intertrait correlation between field dependence and spatial ability to be indistinguishable from one. On this basis, we question whether field dependence should be viewed as a construct that is distinct from spatial ability.

The construct of spatial ability plays a key role in theories of intelligence. Spatial ability is an individual's skill in perceiving fixed geometric/spatial relations and in applying mental transformations such as rotation or reconfiguration to existing spatial relations (cf. Anastasi, 1976). This construct holds a fundamental position in multiple-factor theories of intelligence (e.g., French, 1951; Thurstone, 1938) and in hierarchical theories of intelligence (e.g., Vernon, 1960) and has done so for a long time (see, e.g., Kelley, 1928). Furthermore, spatial ability is recognized as distinct from other fundamental dimensions of intelligence, such as verbal ability (cf. Cattell, 1971). McGee (1979) provides a thorough review of the research on spatial ability, indicating its solid footing in the psychometric literature.

*This research was partially supported by grant A7459 from the Natural Sciences and Engineering Research Council of Canada to the first author. The paper was written while the first author was on study leave at the University of Queensland. We appreciate the helpful comments of Earl Hunt and Steven Schwartz.

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As an outgrowth of the "New Look" movement in perception (cf. Klein & Schlesinger, 1949), field dependence is a relatively new personality construct (Witkin et al., 1954). It is defined as the degree to which a person can overcome embedding context in perception (Witkin et al., 1954) and as the extent to which a person tends to use social context for self-definition (Witkin, Goodenough, & Karp, 1967). Numerous studies—indeed, over 3,000 (Cox, 1980)—have demonstrated the power of field dependence measures in settings as diverse as predicting dropouts from alcoholic therapy (Karp, Kissin, & Hustmyer, 1970) and techniques for conflict resolution (Oltman, Goodenough, Witkin, Freedman, & Friedman, 1975). In their comprehensive catalogue of research on field dependence, Witkin and Goodenough (1981) detail the wide application of this construct in psychology.

There is, however, a problem, in that the two constructs appear to be linked. Even a naive observer could not help but notice the surface similarity of the tests used to measure the two traits. Spatial ability typically is measured by skill in manipulating two-dimensional or three-dimensional puzzle pieces, or by skill in performing mental manipulations such as folding a shape. Field dependence is indexed by accuracy in orienting oneself or an external object with respect to the gravitational upright, or by success in isolating a particular geometric pattern inside a larger pattern. This similarity has not escaped the attention of investigators over the years (e.g., Cronbach, 1970; Horn, 1976). In fact, the question should not be whether the two traits are related, but to what extent they are related.

Our concern in this article is with the degree of overlap between these two constructs. Of course, this issue has been of concern to other investigators as well. At the empirical level, Gardner, Jackson, and Messick (1960) examined the relation of the two most frequently used measures of field dependence, the Embedded Figures Test and the Rod-and-Frame Test, to a standard measure of spatial ability, the Guilford–Zimmerman Spatial Orientation Test. The two field dependence measures correlated .53 and .35, respectively, with the single measure of spatial ability. As McGee (1979) points out, Thurstone (1944) and Podell and Phillips (1959) found similar correlations (and see also Gough & Olton, 1972). McKenna (1984) summarizes the data of 10 other studies (27 correlations) exhibiting a median correlation of .51.

Sherman (1967) has made the point quite forcefully with respect to sex differences in these traits. Her claim is that the frequently reported sex differences in field dependence (e.g., Bigelow, 1971) are an artifact of these same sex differences in spatial ability (e.g., Maccoby & Jacklin, 1974). Nor is she alone in making this claim (see McGilligan & Barclay, 1974). Thus, whether one looks at the entire population or subdivides it, there is strong evidence that the two traits are related.

Additional evidence can be drawn from the factor analytic literature. Several studies have shown that tests of these two traits tend to load on the same factor

(Gardner et al., 1960; Hyde, Geiringer, & Yen, 1975). Indeed, Hyde et al. provide support for Sherman's claim by showing that sex differences in field dependence disappear when spatial ability differences are removed. Widiger, Knudson, and Rorer (1980) carried out a large-scale factor analytic study from which they argued that the two traits loaded onto the same ability factor. Taking all of these types of evidence together, the strong suggestion is that the relation between the two constructs is not inconsequential. Should the apparent similarity between the two traits be a matter of concern? We cannot tell without a better index of that similarity.

Until very recently, unbiased estimation of the relation between traits has been impossible. Random error and method factors obscure estimates, biasing the observed correlations toward zero. However, confirmatory factor analysis techniques provide a means of eliminating these biases. In particular, the maximum likelihood method for the analysis of covariance structures (Jöreskog, 1970, 1971) provides a useful tool for testing hypotheses about mental constructs, their relation to each other, and the sources of error that may influence estimation. Our single aim in this article is to apply this type of analysis to the problem of the relation between field dependence and spatial ability.

The logic of the study is straightforward. From each domain, field dependence and spatial ability, two marker tests were selected. As spatial ability indices, we chose the Spatial Relations subtests of the Multiple Aptitude Tests and the Blocks Design Test from the WAIS. As field dependence measures, we chose the Rod-and-Frame Test and the Embedded Figures Test. Each is recognized as a standard measure of its associated trait, and there is a manipulative and a paper-and-pencil test of each trait. To estimate within-test reliability, two versions (or parts) of each test were used. We will now describe in detail the administration and analysis of these tests.

METHOD

Subjects

Sixty subjects, 30 male and 30 female, were selected from a larger pool of 134 undergraduates between 19 and 24 years of age. All were students at the Scarborough Campus of the University of Toronto. Selection was based upon scores in the 2–Dimensions and 3–Dimensions Spatial Relations subtests of the Multiple Aptitude Tests. Based on mean percentile ranks, 6 men and 6 women were selected from each quintile of the range. In this way, the sample of spatial ability was stratified, as is the case in the test's standardized sample.

Psychometric Tests

*1. **Tests of Field Dependence.*** The tests of field dependence were the two tests most widely used to define the trait (cf. Witkin & Goodenough, 1981). The paper-and-pencil measure was the Embedded Figures Test (Witkin, Oltman, Raskin, & Karp, 1971), in which the individual is required to locate a simple geometric figure in a complex, colored design. Henceforth, the first block of trials is called Embedded Figures–A, the second, Embedded Figures–B.

The manipulative measure of field dependence was the Rod-and-Frame Test (developed by Witkin et al., 1954). We chose the Oltman (1968) version, with slight modifications. The procedure involves seating the subject in a darkened room facing a 42-in. (106.7-cm) luminous square frame containing a 39-in. (99.1-cm) luminous rod at its center. The subject's task is to adjust the rod to gravitational upright in 3° increments by giving verbal instructions to the experimenter. The task is made difficult by tilting the rod, frame, and subject independently. To accomplish this, the subject is seated 7 ft (2.13 m) from the frame in a chair which can be tilted 28° to the left or right. The frame and rod also were tilted at 28° from vertical to the left or right, depending on the trial. The first block (Block A) was conducted with the chair tilted left, the second (Block B) with the chair tilted right. The combination of chair and frame tilt was counterbalanced, and the standard absolute errors scoring system was employed (cf. McGarvey, Maruyama, & Miller, 1977).

*2. **Tests of Spatial Ability.*** Our spatial ability tests were chosen because of their widespread use in the psychometric literature. Of course, there are many more tests of spatial ability than there are tests of field dependence to choose from (cf. Smith, 1964). We chose as our paper-and-pencil measure of spatial ability the Spatial Relations subtests of the Multiple Aptitude Tests (Segal & Raskin, 1959). In each subtest, a target figure could be created from one of four alternatives displayed. In 2-Dimensions, this took the form of a jigsaw puzzle; in 3-Dimensions, the task involved mental paper folding.

The manipulative test of spatial ability was the Blocks Design subtest of the WAIS (Matarazzo, 1972; Wechsler, 1958). Here, the subject is shown a pattern on a card and then must construct that pattern within a specified time interval from a set of blocks that is provided.

*3. **Test of Verbal Ability.*** We also administered a standard test of verbal ability, the Lorge–Thorndike Verbal Battery (Lorge, Thorndike, & Hagen, 1964). Form A, Level 5 of the Verbal Battery consists of the following subtests: word knowledge, sentence completion, arithmetic reasoning, verbal classification, and verbal analogies.

Procedure

The study was conducted in two sessions. The first, which lasted 80 min, included the following tests in the order listed: (1) Spatial Relations–Two Dimensions (*SR–2D*), Lorge–Thorndike Verbal Battery (*LTV*), and Spatial Relations–Three Dimensions (*SR–3D*). The second session varied in duration, depending on the skills of the subject, from 45 min to 2½ hr, with a median time of approximately 1 hr, 5 min. This session included, in the order listed, the following tests: Embedded Figures Test A (*EF–A*), Rod-and-Frame Test A (*RF–A*), Blocks Design (*BD*), Embedded Figures Test B (*EF–B*), and Rod-and-Frame Test B (*RF–B*).

Subjects were tested in small groups in the first session. Of the 134 tested in this first session, 60 were selected on the basis of their Spatial Relations scores for individual testing in the second session. All testing occurred during a single 13-week term.

For all tests except the Rod-and-Frame, instructions to examinees were taken directly from the examiner's manual. For the Rod-and-Frame, Oltman's (1968) instructions were used. To avoid confounding possible order effects with individual differences, tests were always administered in the same sequence. Two versions of each field dependence test were administered to permit estimation of reliability. Reliability of the Blocks Design test was calculated using odd and even trials as separate tests, and a low bound on the reliability of the Spatial Relations test was estimated from the two subtests.

RESULTS

Table 1 presents summary statistics on each of the tests, separately for the two parts of that test. Also included are estimates of reliability; all are derived from the present study except that for verbal ability, which is the published value for alternate forms of the test. As explained above, these reliabilities are the correlations between two versions of each test (cf. Table 2). Because these values are uncorrected for the length of the combined subtests, they are conservative estimates.

TABLE 1
Means, Standard Deviations, and Reliabilities for All Tests

Test Name	Test Abbreviation	Mean	Standard Deviation	Reliability
Spatial Relations–2D	SR–2D	14.48	6.70	.74
Spatial Relations–3D	SR–3D	14.00	4.16	
Blocks Design–Odd Items	BD–O	21.85	2.34	.51
Blocks Design–Even Items	BD–E	19.83	4.04	
Embedded Figures–Part A	EF–A	45.36	24.42	.82
Embedded Figures–Part B	EF–B	29.40	25.68	
Rod-and-Frame–Part A	RF–A	8.32	4.42	.73
Rod-and-Frame–Part B	RF–B	6.45	5.61	
Lorge–Thorndike Verbal	LTV	65.40	7.72	.86

Note: In all cases, reliabilities represent correlation coefficients for the two versions of that test, except for the test of verbal ability, where the published value for alternate forms has been tabled.

TABLE 2
Correlations among the Nine Subtests

	SR–2D	SR–3D	BD–O	BD–E	EF–A	EF–B	RF–A	RF–B
SR–3D	.74							
BD–O	.41	.48						
BD–E	.56	.59	.51					
EF–A	−.75	−.64	−.45	−.56				
EF–B	−.60	−.51	−.44	−.50	.82			
RF–A	−.47	−.51	−.50	−.37	.46	.44		
RF–B	−.46	−.42	−.45	−.42	.49	.53	.73	
LTV	.21	.34	.14	.16	−.26	−.22	.00	.11

Table 2 presents the correlations among the nine subtests displayed in Table 1. Except for those correlations involving verbal ability (the bottom row of the table), all are significantly different from zero, $p < .01$. The absence of any relation with verbal ability was expected (cf. Bock, 1973; Cattell, 1971). Setting aside the verbal ability correlations and the four within-test correlations used as reliabilities in Table 1, and ignoring sign, the median correlation among the spatial ability and field dependence tests in Table 2 is .48, with a range from .37 to .75. Even at this preliminary level of analysis, the spatial ability and field dependence measures are quite strongly correlated.

The Relation between Traits: Model Testing

The purpose of this study was to estimate the relation between two constructs, spatial ability and field dependence. The specific model that we tested is depicted in Figure 1. Using the eight measures (other than verbal ability) shown in Tables 1 and 2, six factors were defined. Two factors represented the field dependence and spatial ability traits, whereas four factors represented the specific variance contributed by each of the four types of test. The factor loadings are shown in Table 3.

With the exception of the critical relation between the two interesting psychological traits, all of the other intertrait relations were fixed to zero. One other constraint was necessary. Inspection of Figure 1 reveals that each specific factor was related to its experimental measures by four parameters, two factor loadings and two error variances, one each from both marker tests. Under LISREL–V, the analysis package used to test our model, such a pattern is not identified. To resolve this problem, we chose to fix equal the values of each pair of specific factor loadings (represented in Figure 1 by dashed lines). This solution was favored because it permitted the loadings on the two psychological traits to vary freely. It is equivalent to replacing the specific factors with correlated errors between the individual test pairs.

The resulting model, where the relation between the two critical psychologi-

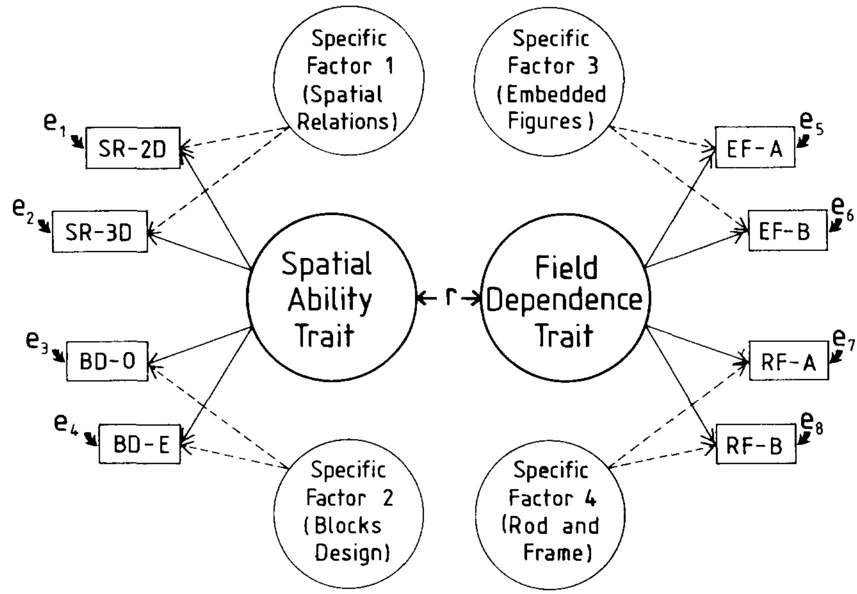

FIG. 1. The factor model used to examine the relation between the field dependence trait and the spatial ability trait. Analysis was carried out using LISREL–V, with the loadings for each pair of subtests (the dashed lines) set equal on each specific factor. Each subtest has associated with it a unique error variance, indicated by the subscripted *e*s. The absence of connections between all factors other than spatial ability and field dependence indicates these relations have been fixed at zero.

TABLE 3
Factor Loadings for the Eight Subtests on the Six Factors

Test	*Factor 1* (Spatial Relations)	*Factor 2* (Blocks Design)	*Factor 3* (Embedded Figures)	*Factor 4* (Rod-and-Frame)	*Factor 5* (Spatial Ability)	*Factor 6* (Field Dependence)
SR–2D	{ .27				.83	
SR–3D					.78	
BD–O		{ .36			.56	
BD–E					.67	
EF–A			{ .51			.82
EF–B						.68
RF–A				{ .63		.58
RF–B						.56

Note: The loadings on the specific factors, Factors 1 to 4, were set equal in these analyses.

cal traits is free to vary, is shown in Figure 1. The LISREL–V estimate of the relation between field dependence and spatial ability was $\hat{r}$ = 1.03, with a standard error of .08. A X^2 goodness of fit test produced a nonsignificant value, $X^2(15) = 18.97$, $p > .20$, indicating that this model provides a reasonable account of the data. Furthermore, the intertrait relation apparently is a strong one.

Consider now the same model, but with the correlation between the two critical traits set at $r = 1$. Here again, the goodness of fit test was nonsignificant, $X^2(16) = 19.12, p > .20$. More important, the X^2 difference was $X^2(1) = 0.15$, which is clearly nonsignificant. Although not surprising, given the estimate of r obtained from the free version of the model, this second run indicates that the critical correlation could indeed be perfect.

To provide a lower bound, the third run of the model set the critical correlation at $r = .8$. Here, the goodness of fit test produced $X^2(16) = 24.65$. The difference between this value and that observed in the free run of the model was significant, $X^2(1) = 5.69$, $p > .05$. Thus, in the context of the present model, the correlation between field dependence and spatial ability cannot be less than $r = .8$. It is time now to consider the implications of these results.

DISCUSSION

Is field dependence distinct from spatial ability? In the most direct attack to date, we found no evidence to support such a distinction. The important new feature of our study was the use of a statistical method that avoids understating intertrait correlations due to random error and method factors. Although understatement usually is desirable when the goal is to detect correlations significantly different from zero, the drawback emerges when testing whether a correlation differs from one. The LISREL analysis does not have this disadvantage. Still, this is a very complex issue, and we cannot discount the distinction between the two constructs without considering the sensitivity of our study., in addition to several possible qualifications on our conclusion.

Four objections to the present arguments suggest themselves, and we will consider each in turn. First, and most obvious, it might be argued that we are advocating acceptance of the null hypothesis that the correlation between field dependence and spatial ability is equal to one. This objection is readily avoided by reformulating the problem in terms of what smaller candidate correlations can be rejected. Put this way, our conclusion is to reject any and all hypotheses specifying this correlation to be less than $r = .8$. No previous study has specified a lower bound this high.

A second objection that might be raised concerns the nature of the sample used in the study. In particular, the use of a sample stratified on the basis of spatial ability, rather than stratified on both abilities or randomly sampled, raises a technical problem: The correlations between the spatial ability tests and the field dependence tests may be inflated relative to those estimated from a random sample. To estimate an upper bound on any possible inflation, one could compare the reliabilities of the spatial ability test (Spatial Relations) on the random sample of 134 subjects versus the stratified sample of 60 subjects. Selection increased reliability only slightly, from .68 to .74. Thus, our asymmetric stratification could not have exerted much influence on the study overall.

A third possible objection always exists in individual differences studies of this sort: Is the use of a university sample appropriate for testing the hypothesis in the first place? Of course, it is conceivable that these two traits are more distinct in the general population than in the university subset. But it must also be recognized that the university population is important in its own right, and has been the basis of the bulk of the literature on field dependence (cf. the studies cited in Cox, 1980; Witkin & Goodenough, 1981).

A fourth potential objection relates to the incomplete modeling of method factors. Put simply, any shared method factor(s) in the spatial ability and field dependence tests would bias the observed correlation toward one. Resolution of this problem would, however, require a much more complete theory of method factors, and inclusion of additional measures of these methods in the study. In the absence of such a theory, we selected the most frequently used measures to examine. For these measures, method factors were chosen to bias the trait correlation toward one, which is to be preferred for a conservative test of $r = 1$. Of course, it must also be noted that such biasing factors are only a possibility.

The last three possible objections that we have discussed all might have biased the focal intertrait correlation toward one. It is for this reason that we have considered each of them explicitly. Nevertheless, having considered them, we would not want them to overshadow the ways that the present study overcomes the longstanding bias toward low correlations in this domain. Our view is that the burden of proof is with those claiming distinct traits. The present attempt to demonstrate any difference using a conservative test certainly failed. On this basis, we maintain that the distinction between field dependence and spatial ability must be questioned.

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