
Handbook of Modern Personality Theory

EDITED BY

Raymond B. Cattell


*Professor Emeritus, Department of Psychology
University of Illinois*

and

*Resident, Department of Psychology
University of Hawaii, Honolulu*

Ralph Mason Dreger

*Professor, Department of Psychology
Louisiana State University*

 HEMISPHERE PUBLISHING
CORPORATION

Washington London

A HALSTED PRESS BOOK

JOHN WILEY & SONS

New York London Sydney Toronto

Multivariate Perspectives on the Construct Validity of the Trait-State Distinction

John R. Nesselroade
The Pennsylvania State University, University Park

Thomas W. Bartsch
Iowa State University, Ames

1 THE IMPORTANCE OF CHANGE CONCEPTS IN PSYCHOLOGY

Terms such as state, mood, affect, and emotion currently abound in theoretical statements about human behavior. As do a number of conceptual labels, these terms create few problems and are seemingly very useful when wielded at a purely verbal level. But as soon as one attempts to lure them into a more rigorous framework, they may be found to be too elusive to permit the integration of theory and related observation into a coherent system. Such concepts tend to be unsuitably flexible when verbally transported from one context to another, unless they can also be tied to a set of explicit operations and procedures and handled with objectivity and rigor.

Our aim in this chapter¹ is to examine certain aspects of psychological change, paying special, though not exclusive, attention to a class of short term, more or less reversible, change phenomena manifested in human behavior. Although the writers are in sympathy with the notion that what is

needed eventually are formulations that locate these concepts in empirically based antecedent-process-consequent schemes, our emphasis here is on determining a structural framework to encompass simultaneous changes in a variety of responses rather than intensive examination of one (or a small number) of response variables in relative isolation.

The present approach emphasizes deriving concepts or constructs directly from data as the initial step in the process of technically advanced theory construction, although it is clear that one's starting point can seldom be considered as beginning purely from either (a) data and advancing to theory, or (b) theoretical considerations and proceeding to data. Perhaps Adam had a clear choice, but for obvious reasons contemporary psychology has been denied the possible benefits of his introspections.

In the study of human behavior, as much as in any other scientific discipline, concern for various aspects of substantive change has prompted a major portion of the total research effort. Almost all branches of psychology, including those dealing with development, learning, pathology, social interaction,

¹Originally drafted while the authors were at West Virginia University.

motivation, physiology, and so forth, are engaged in attempts to establish lawful relationships among changeable events. Many concepts depending on change measurement for their definition—such as maturation, degenerative process, trait change, complex state change, learned defense mechanism—have been employed in these fields with an almost complete lack of necessary operational definition. We here examine some of these concepts—principally those of state and trait change—in the hope of putting them on firmer conceptual footing.

In choosing to investigate the behavior of living organisms, the researcher sets for himself an arduous task in which he will often be confronted with frustrating events and, occasionally, with minor triumphs. The villain in the piece frequently is change (Bereiter, 1963), which either occurs when it is unexpected or which fails to occur when it is anticipated. From conception to senescence, the organism undergoes countless chemical, physiological, anatomical, and psychological modifications. Some of these changes take place rather slowly, as in the gradual ossification of skeletal structures, the development of motor skills, and the elaboration of an adequate repertoire of socially acceptable responses. Others, such as amitosis and autonomically controlled adaptive responses, may occur at prodigious rates.

In addition to changes occurring in the organism, the environment surrounding it is also constantly altering in an endless panorama of stimulation. These two kinds of changes—organismic and environmental—are not independent; they influence, cause, and otherwise modify each other, sometimes simply, but often in complexly interwoven patterns. The environment, though no more stable in many respects than the organism, is the more durable. One result of this arrangement is that responsibility for survival, both

physical and social, eventually falls to the organism, which must adapt its behavior to meet environmental demands. Successful adaptation may require altering the environment, the organism, or both.

In contrast to changes in the organism, we may introduce briefly at this point another notion, stability. Distinguishing changes within the broader context of behavior implies at least one other classification which for present purposes we will simply refer to as stability. Personality theorists, for example, have long been concerned with the permanent characteristics and attributes of the organism. This stability has been sought largely in two main areas: (a) stability of endowment or levels on measured attributes, and (b) stable, recurrent patterns of, and relationships among, changeable events. Ability and temperament traits are examples of the former, and processes such as learning and maturation exemplify the latter.

Put simply, the idea emphasized here is that as one of its attributes the organism is capable of being, in some sense, a "different" organism from one occasion to another as it behaves over time. In what way or ways is it a different organism from one point in time to another? In what ways does it remain the same? How can we define and describe both dimensions of change and dimensions of stability for the organism? These and related questions are discussed in subsequent portions of this chapter. First, however, a brief digression is in order, to provide some orientation concerning the particular methodological approach around which later discussion centers.

2 USE OF MULTIVARIATE METHODS IN STRUCTURING CHANGE

If the complexities of psychological change are to be dealt with successfully, the

establishment of lawful relationships should center on appropriately basic and unitary response dimensions. Multivariate methods offer tools for systematic examination of a large number of variables as they change, thus enabling a researcher to determine which variables in a set actually manifest a tendency to change together in a patterned, unitary fashion (Nesselroade, 1970, 1976). These composite variables and the constructs inferable from them would seem, in the long run, to offer the most potential information and theoretical utility if intraindividual variation is to be structured.

Any single observable variable that one might select for study is liable to be affected by a number of influences other than the particular phenomenon it is supposed to index, and almost certainly it is not the optimum observation in terms of which to seek some law. As Cattell (1946), Cronbach (1957), and others pointed out long ago, rarely can a single measured response adequately index a psychological construct. Using multivariate analysis procedures, the single, observable variables, each of which tends to be pulled and pushed about by numerous forces, are really mere stepping stones to the more stable patterns of intraindividual change.

The establishment of concepts by means of carefully done factor-analytic studies has the advantage initially of putting one in the position of knowing which manifestations do not belong to the concept as well as knowing which ones do belong. Such information is crucial in rigorously distinguishing among dimensions of response. For example, it was pointed out (Cattell & Nesselroade, 1976) that much confusion has arisen from using terms such as anxiety, fear, stress, and threat almost interchangeably. The argument is that anxiety, stress, and fear can be distinguished factor analytically as distinct response patterns, and that once the response

patterns are uniquely identified the question as to what classes of stimulus situation elicit the given response can be systematically investigated.²

Since the advent of individual-differences quantitative methodology as an approach to the dissection of behavior, the search has been conducted for more or less stable dimensions of interindividual variability that permit the symbolic representation of a given person as a set of numbers. These numbers, in turn, can be conveniently utilized in functional expressions to predict that individual's performance on some relevant task or behavior. Historically, this approach has been most pronounced in the area of human abilities, which developed in intimate contact with the best known, perhaps, of multivariate methods—factor analysis. The ensuing dimensions (factors) of covariation among tasks presumed to reflect ability attributes tended to assume the status of relatively fixed characteristics of the individual, and the conceptual label *trait* was seemingly tied closely to a highly sophisticated and powerful quantitative procedure. Or as Horn and Little (1966) expressed it, "because it is sensible to suppose that abilities are stable, it has been assumed that factors found among ability test performances must represent traits."

It is perhaps a little curious that the trait concept became entrenched so firmly in this context, for factor analysis, in and of itself, as usually done on a cross section of subjects at one point in time (*R* technique, see chapter 1), logically cannot be claimed to yield only factors which are stable in terms of a person's implied endowments (scores) thereon. We shall make an important distinc-

²It is worth noting that the logic of the multivariate approach can be applied to the stimulus domain also. Frederiksen (1972) surveyed past attempts and suggested directions for further research along these lines.

tion here, and elaborate it later, between a stable pattern of factor loadings or one kind of factor *invariance* (Thurstone, 1947) and *stable* factor scores.

More than 50 years of factor-analytically-oriented research have not succeeded in yielding a set of traits, cognitive or otherwise, by which we can bring the prediction of behavior in general to the desired level of precision. Obviously, in a prediction scheme of the type mentioned previously in which a person's relevant endowments are specifiable as quantities, it is advantageous to deal in attributes that are stable to the point that, once measured, the obtained values can be used a week, a month, or a year later and still be appropriate. But if this type of information is not sufficient to the task, then clearly other information must be used.

An alternative kind of predictor information to which many theorists are now turning is provided by the situation in which the behavior will occur (see Patterson and Bechtel, chapter 10). Others, however, after many years of trying to get "inside the organism," are understandably reluctant to participate in an unceremonious exit back to the environment (at least not without taking along their more cherished discoveries). Our concern here, however, is not directly with these as mutually exclusive alternatives but rather with a possible point of overlap to the extent that situations and their effects can be tied to dimensions of interindividual and intraindividual response variability.

3 INTRAINDIVIDUAL DIFFERENCES AND *P* TECHNIQUE

We can further define the topic of interest here and at the same time discuss one of the techniques currently being employed to reveal structure in intraindividual variation by considering briefly the methodology known as *P*-technique factor analysis (see

chapters 9 and 10). In *P* technique one person is used as a source of data. This individual is measured on a selected set of attributes on a large number of occasions.³ Each occasion of measurement, which typically involves the complete set of measures, may be at regular or irregular intervals depending on the experimenter's objectives (Cattell, 1966e). For example, the person might be measured once a day for a period of 100 to 150 days. The extent to which his scores on a given measure vary from day to day across the testing period reflects the magnitude of intraindividual variation. Moreover, the observation that two or more variables tend to covary across time may be taken as evidence (Bereiter, 1963) supporting the notion that the variables are, to an extent reflected in the magnitude of the association, measures of the same thing.

It is important to note that the covariance among two or more variables over time may result from either a single underlying common source or multiple underlying sources. Or, alternatively phrased, more than one common factor may be contributing to the observed covariance. What and how many such dimensions (factors) are involved? In a *P*-technique study, one attempts to answer this question, not just for two variables but for many, by a factor analysis of the covariances among all the variables in the original battery of measures. That is to say, using data obtained from the repeated assessment of one person, the variables are intercorrelated over the total number of occasions, the results are arrayed into a correlation matrix, and the matrix is then factor analyzed. The resulting factors represent a set of dimensions of intraindividual variability. Note that the source of variability *ostensibly*

³ Karen Cattell, in 1946, was the first recorded subject for a longitudinal factor analysis on this basis (Cattell, Cattell, & Rhymer, 1947).

studied in the typical *R*-technique (cross-sectional) factor analysis—interindividual variation—is eliminated from the beginning by measuring only one subject.

P technique is perhaps one of the most promising of several methods used to ascertain the structure of intraindividual variation. Writers such as Anderson (1961), Holtzman (1962), and Horn and Little (1966) criticized it on certain counts and others, most notably Cattell (1963d), defended it. A review of *P*-technique studies by Luborsky and Mintz (1972) is generally pessimistic concerning the cross-person replicability of these intraindividual change dimensions. Bath, Daley, and Nesselroade (1976) and Lebo (1972), however, in a series of *P*-technique analyses designed to examine replicability more directly, found several factors well-replicated among subjects.

A point worth making here is this: Assuming we can structure and measure intraindividual response variability at this level of refinement, it then becomes possible to study the effects of changing situations on behavior while also retaining the integrity of trait structures. That is, we can accommodate situationally induced changes in the organism and its behavior, while still allowing for stable dimensions of interindividual differences.

4 TWO MAJOR ASPECTS OF THE STUDY OF CHANGE

The nature of factors derived in a change context depends on the nature of the data being factor analyzed. That stable (in a test-retest sense) factors may be obtained from stable variables seems clear enough. If, on the other hand, the variables being measured show a great deal of interoccasion fluctuation, one cannot expect to derive only stable, trait-like factors from them. We will pursue this point more fully in section 5.

Attempts to deal in a logical but quantitatively rigorous manner with change data have unearthed a number of apparent controversies, contradictions, and dilemmas of one form or another (Bereiter, 1963; Cronbach & Furby, 1970; Lord, 1963; McNemar, 1958). Unassailable logic and usable quantitative procedures cannot always be blended together to produce completely satisfactory answers to pertinent questions concerning change. We can recognize two major problem areas: (a) questions of measuring and scaling change data per se; and (b) the development and use of models for exploring change structure. The first of these is admittedly an important, even crucial area, but space does not permit our delving into it. A number of discussions of significant aspects of the problems involved may be found in the volumes edited by Cattell (1966e) and Harris (1963b) as well as in other recent papers such as those by Cronbach and Furby (1970) and Tucker, Damarin, and Messick (1966).

In this chapter we are more concerned with the second problem area, namely, models for studying change structures. An impressive collection of designs and techniques has been proposed for analyzing the structure of data which contain change information (e.g., Baltes & Nesselroade, 1970, 1973; Bentler, 1972; Cattell, 1966e; Corballis & Traub, 1970; Harris, C. W., 1963a; Horn, J. L., 1963, 1966; Tucker, 1963). Many of them involve variants of the basic factor-analytic model. For example, Tucker's three-way generalization of factor analysis offers a means of including multiple sets of *P*-technique-type data, i.e., *variables by occasions* score matrices for more than one person within the framework of a single analysis, as does Cattell's population *P* technique and Horn's discriminant function approach. In discussions focusing on the application of multivariate models to the

study of developmental phenomena (Baltes & Nesselroade, 1973; Baltes, Nesselroade, & Cornelius, 1976), suggestions were made concerning the nature of the formation and change of multivariate psychological structures and how to empirically study it using models such as the factor-analytic one.

The remainder of this chapter is concerned with the factor-analytic model. First, its application to some particular kinds of change analyses is discussed and then a brief overview of some of the more recent empirical results from applying this model to the substantive area of personality change is given.

5 INCLUSION OF BOTH INTER-INDIVIDUAL AND INTRAINDIVIDUAL DIFFERENCES DIMENSIONS WITHIN THE FACTOR-ANALYTIC MODEL

One of the factor-analytic techniques for structuring change (*P* technique) was given some discussion in section 3, primarily to introduce the notion of dimensions of intraindividual variation. We now augment that discussion with the following: (a) by presenting a more concise statement of the factor model; (b) by tying it to a concrete example of one kind of experiment and data analysis in which it may be used; and (c) by bringing together within a single conceptual framework both dimensions of interindividuality and intraindividual response variability.

A rather common situation in studying change is that in which a sample of subjects is measured on a battery of tests—a treatment in the form of either some direct, controlled manipulation, or just the onslaught of life's events during a specified time interval—is administered and the persons are then retested using the same battery. Assuming that differential changes in people's scores exist from Time 1 to Time 2, a legitimate objective is to ascertain if, and for which variables, the scores tended

to change together as a functional unit.

Cattell (1966e) suggested the more or less straightforward factoring of the intercorrelations of the algebraic difference scores (Occasion-2 scores minus Occasion-1 scores) as the way to determine patterns of change across multiple measures. This method, labeled differential *R* technique (or *dR* technique) was examined in detail elsewhere (Nesselroade 1970, 1973) and various modifications, such as using mean cross-products of differences instead of correlations, proposed and tried out on empirical data. In addition to the more parochial objection to this approach—"it involves the unreliable difference score"—Humphreys (1961) and J. L. Horn (1963) condemned it on other, more scholarly grounds. Although the matter has not blossomed into an ostentatious debate, at its base lies a compelling point that, on examination, leads naturally into the introduction of a simple model encompassing both traits and states.

Humphreys contended that little, if any, justification exists for working directly with the difference scores since no factors are present in the differences which are not also present in the separate occasions (cf. Woodrow, 1939).⁴ He argued against reifying the differences by dealing with them directly. Cattell (1966e) suggested that the alternatives and subsequent necessity for indirectly finding the change pattern by inference from the factor patterns of distinct occasions may lead to problems of such magnitude that factoring the differences directly may be the more fruitful approach.

A resolution to this controversy, which also sheds considerable light on the conceptual distinction between trait and state, may be reached by examining closely the me-

⁴A similar conclusion was reached by Harris (1963a) in developing a method of structuring two-occasion change data by means of canonical factor analysis and normal varimax rotation.

chanics of difference score factoring starting with the factor-analytic-specification equation (chapter 1) defined in such a way, it seems, as to be agreeable to both positions. First, consider a form of the basic specification equation:

$$a_{ji} = v_{j1}S_{1i} + \dots + v_{jk}S_{ki} + u_{ji}. \quad (1)$$

Equation 1 simply states that response a_j (Act j) of individual i is a weighted sum of his factor scores. The v_j s are the weights (factor loadings) indicating the contribution of a particular factor to performance a_j , the S s are individual i 's factor scores, and u_j is a factor that is unique to performance of a_j (the variance of u_j includes both specific and error variance).

A general expression for a set of specification equations for N individuals on n behaviors using matrix notation can be written as⁵

$$A' = V_{fp}S'_f, \quad (2)$$

where A (prime denotes transposition of matrix) is an $N \times n$ matrix of scores for N individuals on n variables, V_{fp} is an $n \times k$ matrix of factor loadings, and S'_f is an $N \times k$ matrix of factor scores. For simplicity we have omitted the specific factors, but relevant comments concerning them will be made at appropriate places in the subsequent discussion. We further specify that the columns of both A and S'_f (rows of A' and S'_f contain deviation scores; that is, each column of A and S'_f has its mean equal to zero.

Next a set of specification equations is defined for each of two occasions involving the same subjects (N) and variables (n) as

⁵The notation used here conforms as closely as possible to that suggested by Cattell (1966e). Where no confusion is likely to arise, various subscripts have been dropped for the convenience of all involved.

$$A'_1 = V_{fp1}S'_{f1} \quad (3)$$

and

$$A'_2 = V_{fp2}S'_{f2} \quad (4)$$

such that

A'_1 and A'_2 are of order $n \times N$,

S'_{f1} is of order $k_1 \times N$,

S'_{f2} is of order $k_2 \times N$,

V_{fp1} is of order $n \times k_1$,

V_{fp2} is of order $n \times k_2$, and

k_1 may or may not be equal to k_2

Thus far, we have simply stated that the scores on the variables for a given occasion are weighted sums of the individual's factor endowments on that occasion. Nothing has been said about the nature of the factors, i.e., whether they are the same (in some sense) from one occasion to the other.

Next, consider the following 2×2 table:

Factor loading pattern	Factor scores	
	Stable	Fluctuant
Invariant	a	b
Not invariant	c	d

One can conceive of a given factor falling in one of the four cells. For example, cell a factors would not only show the same loading pattern on both occasions, but people would also tend to maintain their level of endowment from Time 1 to Time 2.⁶ Cell b

⁶As is well known to those working in the field, the problems of finding and evaluating factor invariance are by no means solved. The theoretical presentation in this section obviously benefits from our avoidance of real data and consequent freedom to deal with strict numerical invariance of loading pattern.

factors would also have the same loading pattern across occasions, but scores could vary differentially from Occasion 1 to Occasion 2. Cell *c* factors would show different loading patterns from one occasion to the next, but scores on such factors would tend to remain stable. This might also be taken as evidence for identifying two factors as the same, in one sense, from Time 1 to Time 2. Cell *d* factors in this frame of reference would be the most erratic of the lot and do not offer any firm basis, in themselves, for cross-occasion matching. Nevertheless, Case *d* is needed for completion, and the pessimist is apt to insist that empirical data are most likely to fill this cell. To simplify the presentation, the case of constant changes for all persons on a factor will be treated as either Case *a* or Case *c* (stable factor scores) although this need not be done. Elsewhere (Nesselroade, 1967, 1973), the alternative of identifying such factors as change dimensions has been dealt with in detail. For the present treatment consider that, if all persons' scores changed by some constant amount from Time 1 to Time 2, the inter-occasion correlation would be unity, thus implying perfectly stable factor scores by that mode of assessing stability.

We will take the position that a necessary, though perhaps not sufficient, condition for interpreting a given factor as a trait dimension is that the individuals' scores thereon tend to remain stable.⁷ For various reasons it is desirable also to have factors with invariant loading patterns, but in the case of

traits (in this context) it is not taken to be a necessity. In some cases, one might reasonably expect to identify two trait dimensions even though the loading pattern is not invariant from one occasion to another. Such, in fact, is the position taken by Harris (1963a) in an analysis of ability data in which the factor scores are forced to remain stable, thereby accounting for observed changes as changes in factor structure.

Patterson and Betchel's examination of states and traits (see chapter 10) employs a quite different operational definition of the trait concept than the one being implied in the present discussion. For their developments, trait is a derived parameter for the person based upon his average state level measured over many different situations. By way of contrast, both trait and state dimensions in the present discussion are conceptualized as factors (dimensions of individual differences) potentially operating at any given point in time. Separation of these two types of hypothesized factors is to be made on the basis of temporal characteristics of the factor loading pattern and the individuals' factor scores.

Baltes and Nesselroade (1973) discussed the implications of the 2 X 2 table presented earlier for the study of personality and ability trait development in a life-span context. They paid considerable attention to issues of factor change and stability within a process framework but extensive comment here is not possible.

⁷This statement, as it stands, requires some qualification. Humphreys in 1960 and in subsequent communication strongly argued for researchers to be alert to the possibility of simplex-like relationships among repeated measures on what is ostensibly the same variable. He maintained that the same may be true for test-retest correlations based on factor scores. If so then, by the previous definition of trait, there can be no traits. Given adequate resources, this proposition

of simplices for factor scores can be put to an empirical test, and it may turn out to hold for factors in certain substantive areas (e.g., developmental and growth data) and not for others (e.g., factors related to short term, reversible phenomena such as diurnal fatigue, the estrous cycle, and emotional responses in general). How stable the factor scores should remain and over what time period in order to retain the conceptual label *trait* is discussed subsequently.

Using the fourfold table as a reference point, let us now consider some of its implications for difference score factoring and, more generally, for the distinction between the concepts of psychological traits and states. First, we accommodate two kinds of factors: (a) a set of traits with invariant loading patterns and perfectly stable scores (cell *a* factors) and (b) a set of factors upon which we initially place neither restriction (cell *d* factors). Using these definitions, we may partition the separate-occasion factor-loading patterns (V_{fp}) and factor score matrices (S'_f) as follows:

$$V_{fp1} = [V_t : V_{s1}], S'_{f1} = \begin{bmatrix} S'_{ft} \\ \dots \\ S'_{fs1} \end{bmatrix} \quad (5)$$

and

$$V_{fp2} = [V_t : V_{s2}], S'_{f2} = \begin{bmatrix} S'_{ft} \\ \dots \\ S'_{fs2} \end{bmatrix} \quad (6)$$

where

- V_t = the factor pattern of *t*-trait factors,
- V_{s1} = the factor pattern of $k_1 - t$ Occasion 1 nontrait factors,
- V_{s2} = the factor pattern of $k_2 - t$ Occasion 2 nontrait factors,
- S'_{ft} = the factor scores for *N* people on *t*-trait factors,
- S'_{fs1} = the factor scores for *N* people on $k_1 - t$ Occasion 1 nontrait factors, and
- S'_{fs2} = the factor scores for *N* people on $k_2 - t$ Occasion 2 nontrait factors.

Previously, appropriate matrices were defined as containing deviation scores; thus we can write an expression for the variance-covariance matrix of the difference scores as

$$C_d = \frac{1}{N} [(A'_2 - A'_1)(A'_2 - A'_1)'], \quad (7)$$

where C_d represents the variance-covariance matrix of difference scores and the other symbols are as defined above. For the sake of additional simplicity here, and in later discussion, let us also assume that the standard deviation of each variable remains the same from Occasion 1 to Occasion 2. Such an assumption, which may or may not be empirically justifiable, is not critical for the line of argument we are developing at this point. It should be noted, however, that changes in standard deviation from one testing to the next will exert an influence on the results which, depending on one's method of factoring, will be to some extent predictable. The more mathematically sophisticated student is encouraged to follow through on this (e.g., Kaiser & Caffrey, 1965; Meredith, W., 1964). Substituting the appropriate factor matrix equivalents for A'_1 and A'_2 we have

$$C_d = \frac{1}{N} \left\{ \begin{bmatrix} (V_t : V_{s2}) \begin{pmatrix} S'_{ft} \\ \dots \\ S'_{fs2} \end{pmatrix} \\ - (V_t : V_{s1}) \begin{pmatrix} S'_{ft} \\ \dots \\ S'_{fs1} \end{pmatrix} \end{bmatrix} \cdot \begin{bmatrix} (V_t : V_{s2}) \begin{pmatrix} S'_{ft} \\ \dots \\ S'_{fs2} \end{pmatrix} \\ - (V_t : V_{s1}) \begin{pmatrix} S'_{ft} \\ \dots \\ S'_{fs1} \end{pmatrix} \end{bmatrix}' \right\} \quad (8)$$

When the expression on the right-hand side of Equation 8 is expanded and the terms collected and cancelled, the result can be written as

$$\begin{aligned}
 C_d = & \left[V_{s2} \left(\frac{1}{N} S'_{fs2} S_{fs2} \right) V'_{s2} \right] \\
 & - \left[V_{s2} \left(\frac{1}{N} S'_{fs2} S_{fs1} \right) V'_{s1} \right] \\
 & - \left[V_{s1} \left(\frac{1}{N} S'_{fs1} S_{fs2} \right) V'_{s2} \right] \\
 & + \left[V_{s1} \left(\frac{1}{N} S'_{fs1} S_{fs1} \right) V'_{s1} \right] \quad (9)
 \end{aligned}$$

Now the first and fourth terms in parenthesis in Equation 9 represent within-occasion factor covariance matrices, and the other two terms represent between-occasion factor covariance matrices. These are signified by

$$C_{ij} = \frac{1}{N} S'_{fi} S_{fj} \quad (10)$$

Equation 9 may then be written as follows:

$$\begin{aligned}
 C_d = & V_{s2} C_{s2s2} V'_{s2} - V_{s2} C_{s2s1} V'_{s1} \\
 & - V_{s1} C_{s1s2} V'_{s2} + V_{s1} C_{s1s1} V'_{s1} \quad (11)
 \end{aligned}$$

At this point all terms involving traits (cell *a* factors) have vanished for algebraic reasons, leaving only the other dimensions as defined previously (cell *d* factors). In obtaining Equation 11 we have assumed, aside from the usual assumptions of the factor-analytic model, that (a) the specific factor of a given variable on one occasion does not covary with the specific factors of the remaining $n-1$ variables on the other occasion, and (b) the specific factor of a given variable on one occasion does not covary with any of the common factors on the other occasion.

The factor analysis of a covariance matrix (Tucker, 1951) leads to a general solution of the type

$$C = V_{fp} C_{ff} V'_{fp} \quad (12)$$

C is the variance-covariance matrix of the observed scores (whether difference scores, or otherwise) with the exception that each diagonal element of C represents that portion of the variance of an observed variable due to the common factors only, rather than the total variance of that variable. C_{ff} is the factor variance-covariance matrix and V_{fp} the matrix of factor loadings.

Using partitioned matrices we may write Equation 11 as either

$$\begin{aligned}
 C_d = & [V_{s2} : -V_{s1}] \\
 & \cdot \begin{bmatrix} C_{s2s2} & C_{s2s1} \\ \dots & \dots \\ C_{s1s2} & C_{s1s1} \end{bmatrix} \cdot \begin{bmatrix} V'_{s2} \\ \dots \\ -V'_{s1} \end{bmatrix} \quad (13)
 \end{aligned}$$

or

$$\begin{aligned}
 C_d = & [V_{s2} : V_{s1}] \\
 & \cdot \begin{bmatrix} C_{s2s2} & -C_{s2s1} \\ \dots & \dots \\ -C_{s1s2} & C_{s1s1} \end{bmatrix} \cdot \begin{bmatrix} V'_{s2} \\ \dots \\ V'_{s1} \end{bmatrix} \quad (14)
 \end{aligned}$$

Both Equations 13 and 14 are of the form $C = V_{fp} C_{ff} V'_{fp}$ (Equation 12). Note, however, that, as a function of subtracting the Occasion 1 observed scores from the Occasion 2 observed scores, either the factor loadings for Occasion 1 or the cross-occasion factor covariances are reflected (multiplied by -1.0). We may pause here to consider that

1. The difference score covariance matrix does yield a factor solution.
2. *Traits*, as ideally defined previously, necessarily vanish from the solution when differences are taken.
3. No factors are represented in the differences which are not present on the separate occasions.

One of the pertinent implications of the third point is that, although one may factor analyze an $n \times n$ matrix of covariances, he can expect $k_1 + k_2$ factors, given they are all of the cell d type.

Next we can derive the expected differential- R solution for cell b factors (invariant patterns but fluctuant factor scores) by letting $k_1 = k_2$ and $V_{s1} = V_{s2} = V_s$ and writing Equation 11 as

$$C_d = (V_s C_{s2s2} V'_s) - (V_s C_{s2s1} V'_s) - (V_s C_{s1s2} V'_s) + (V_s C_{s1s1} V'_s) \quad (15)$$

$$= V_s (C_{s2s2} - C_{s2s1} - C_{s1s2} + C_{s1s1}) V'_s. \quad (16)$$

Denoting the expression in parentheses as C_{ss} we have

$$C_d = V_s C_{ss} V'_s. \quad (17)$$

Thus again we have a solution of the type $C = V_{fp} C_{ff} V'_{fp}$. Now, however, each element in the factor variance-covariance matrix is a composite of either four covariance, or two covariance and two variance, terms. Thus, even though the loading pattern of a factor may be invariant over occasions, it can still emerge in the difference analysis, given differential changes in individual's scores on that factor from Time 1 to Time 2. These cell b factors are of primary interest since, of the four types, they best represent our current ideas about psychological states.

The fact that cell b (state) factors will emerge in a dR factor analysis as well as in an R -technique analysis is one plausible explanation for the similarity of factor patterns noted by Cattell and Scheier (1961) and by Hundleby, Pawlik, and Cattell (1965) in comparing dR and regular R -technique factor-analysis results. One interesting ques-

tion for which we have no answer at this point is this: Given that invariant factor loading patterns can be demonstrated, how much instability (function fluctuation) of factor scores will the conceptual label *trait* tolerate? As Cattell (1966e) pointed out in discussing this issue, even a person's height tends to vary systematically over a 24-hour period, yet we tend to think of stature as one of the more permanent attributes of the mature organism. The use of differential- R analysis might provide an operational answer here in that, if intraindividual variation on a factor is sufficient to permit its emergence in a dR analysis, then the label trait is inappropriate for that factor. Before we can say more about this, however, several other points should be considered.

Cell c factors (stable factor scores without invariant patterns) may be examined in a manner consistent with the preceding developments by defining the following expressions:

$$A'_1 = V_{t1} S'_{ft} \text{ and } A'_2 = V_{t2} S'_{ft}. \quad (18)$$

(Here S'_{ft} is used on both occasions since stable factor scores are specified.)

$$\begin{aligned} C_d &= \frac{1}{N} [(A'_2 - A'_1)(A'_2 - A'_1)'] \\ &= \frac{1}{N} [(V_{t2} S'_{ft} - V_{t1} S'_{ft}) \\ &\quad \cdot (V_{t2} S'_{ft} - V_{t1} S'_{ft})'] \\ &= \frac{1}{N} (V_{t2} - V_{t1})(S'_{ft} S'_{ft})(V'_{t2} - V'_{t1}) \\ &= (V_{t2} - V_{t1}) \left(\frac{1}{N} S'_{ft} S'_{ft} \right) (V'_{t2} - V'_{t1}) \end{aligned} \quad (19)$$

Letting $(1/N S'_{ft} S'_{ft}) = C_{tt}$, we have

$$C_d = (V_{t2} - V_{t1})(C_{tt})(V'_{t2} - V'_{t1}), \quad (20)$$

which is of the form $C = V_{fp} C_{ff} V'_{fp}$.

In marked contrast to the outcome for cell *d* factors, the present factor loadings are the *differences* between each loading on Occasion 2 and the corresponding loading on Occasion 1. The last statement, of course, depends on the one-to-one matching of factors across occasions; but that condition was stipulated by the stated restriction of stable factor scores. Thus, in this case (cf. Harris, 1963a) what might be regarded as a kind of trait factor (because of the stability of the individuals' endowments thereon) would still emerge in a difference score factoring although in somewhat mutilated form. Being confronted with a vector of loadings, which, unknown to the analyst, actually consisted of differences between Occasion 2 and Occasion 1 loadings, could make the practice of factor interpretation a most unsavory and indeed frustrating task.

About cell *d* factors we will say little else except that at this point they do not seem as useful as the others from a taxonomic standpoint, although they may become so when one begins to consider how Occasion 1 differs from Occasion 2 in relation to variables external to the factor analysis, and that the algebraic expectation, as mentioned earlier, is that both Occasion 1 and Occasion 2 factors would emerge in a *dR* analysis, the totality of which might be greater in number than one would be willing to extract from *n* variables. This dismissal of case *d* does not imply that such factors are unlikely to crop up. Baltes and Nesselroade (1973) and A. R. Buss (1974) discussed a potential role for such factors in the study of developmental transitions. Also, for example, in experimentation with drugs the effect may not be to shift subjects on replicable dimensions but rather to alter significantly the factor structure of response variables. This could lead to either Case *c* or Case *d* or to some marginally recognizable mixture of both.

This, then, is a brief account of the algebraic relationships between differential-*R* and *R*-technique factor analyses. Admittedly, the well-known problem areas of factor analysis (communality estimation, number of factors, metric invariance, and rotation) have been avoided, but each of these is worth a chapter or more in itself. It has been shown here that the familiar linear model or factor specification equation can accommodate both dimensions of intra-individual change and dimensions of stable individual differences. In the course of the discussion it became apparent that the use of *dR* and *R* technique for isolating and studying these two kinds of dimensions does not, in itself, lead to unequivocal resolutions. On the one hand, differential-*R* technique analysis, as indicated, may yield cell *b*, cell *d*, or "differenced" cell *c* factors described previously. *R*-technique analysis, on the other hand, permits factors representing all four cells potentially to emerge.

It should be clear, therefore, that the investigation of change and stability in psychological measures requires more refined techniques and that these techniques must provide for the simultaneous consideration of structural invariance and temporal stability. Only then can a given factor, with confidence, be properly understood in a trait-state kind of framework and be integrated into a broader theoretical scheme. In the next section, brief discussion is given to a selected set of factor-analytic designs that provide for the simultaneous consideration of invariance and stability issues.

6 LEADS ON SEPARATING TRAIT AND STATE DIMENSIONS

The conceptual scheme embodied in the fourfold table presented earlier has served as a focal point for the preceding discussion concerning the relationships between *dR*-

and *R*-technique factor analysis. Before abandoning that scheme to turn to a discussion of substantive findings, we consider some of its more general implications for research.

One major issue concerns the taxonomic objective of isolating and identifying the different types of factors discussed in section 5. The trait-state distinction appears to be bearing fruit (Singer, J. L., & Singer, 1972), especially in the domain of self-reported anxiety. Methods and procedures for analyzing multivariate change data are being developed; indeed, the area is blossoming into one of exciting methodological innovation and substantive findings. Here we can but hint at some of these although it is clear that the need for a systematic appraisal is beginning to be felt.

In attempting to organize factors (as response patterns) into some classificatory scheme such as the fourfold table, are we to analyze data simply to discover what kinds of factors emerge, or should we proceed by constructing factors with certain features to more carefully explore their other characteristics? Some readers may recognize aspects of the naive-realism-versus-nominalism debate here but we shall refrain from making other than illustrative remarks. In any case, many procedures for analyzing multivariate change data can be ordered with respect to the degree to which constraints on either factor loading patterns or factor scores are specified (Nesselrode, 1976).

Consider, for example, data from two occasion multivariate studies of the type discussed in section 5. We briefly describe here three general approaches to analyzing such data which bear directly on the classification issue. Each one can be elaborated and refined into many particular applications, some of which accommodate more than two occasions of measurement.

First, one might proceed by separately

factoring the data from each occasion of measurement. The two solutions could then be independently rotated to some criterion such as simple structure and the resulting factors evaluated in terms of temporal invariance of loading patterns and stability of factor scores.

Second, a slightly stronger approach would be to employ transformation techniques (e.g., factor matching procedures) deliberately to maximize factor loading pattern invariance, factor score stability, and so forth. The resulting factors could then be studied to see which niche they occupy in the scheme. For instance, one might rotate both sets to maximize invariance of loading pattern and then examine the degree of stability of the implied factor scores. Alternatively, the longitudinal factor analysis model of Corballis and Traub (1970) provides a rotational solution which has been shown (Nesselrode, 1972) to maximize factor score stability coefficients. If either of the two characteristics (invariance or stability) is maximized, the nature of the other is an empirically answerable question.

Third, a still stronger approach is to initially pool data across occasions and factor so as to build in either perfect invariance of pattern or stability of factor scores. The procedure of Harris (1963a), mentioned earlier, constructs factor solutions that exhibit perfectly stable factor scores. Rozeboom (1976) presented an elaborate model for the study of change in multivariate data which constrains the factor-loading patterns to be perfectly invariant across occasions. Hakstian (1971) offered a systematic treatment of procedures for components analysis which parallel closely our Cases *a*, *b*, *c*, and *d*.

These techniques by no means exhaust the possibilities. Cattell's (1966e) grid analyses, J. L. Horn and Little's (1966) discriminant function approach, Tucker's (1963) three mode factor analysis, and the maxi-

mum likelihood methods (Jöreskog & Sörbom, 1975) bring multioccasion data into the confines of a single analysis. In short, many data analysis procedures are now available and are waiting to be evaluated by empirically oriented researchers willing to invest their resources in collecting the necessary, technically demanding, but substantively crucial data.

A second major issue concerns the utilization of factor analytic methods in more traditional manipulative experimental designs. Although the practice of estimating and subsequently analyzing factor scores is abhorred by many, significant theoretical advances in the trait-state domain await the outcomes of studies in which attempts are made to manipulate factor pattern invariance, factor score stabilities, factor score mean differences, etc.

Proper manipulative work, in fact, may free us from the trait-state distinction as such by disclosing that the stability of factor scores, for example, is more fruitfully regarded as a continuum of values, the antecedents of which need to be explored, rather than a loose dichotomy. Explicating the antecedents for various degrees of invariance and stability of response patterns is a promising endeavor not only for the study of personality states, moods, etc., but for the study of personality development and change across the entire life span.

7 SUBSTANTIVE FINDINGS RELATED TO TRAIT-STATE ISSUES

To provide some additional perspective on the trait-state distinction from a factor-analytic viewpoint, the model will be considered in the context of substantive research. Our purpose here is not to be comprehensive but to consider selected research activity as it relates to issues outlined previously. Two areas seem to be among the most relevant.

One issue concerns the numerous and enthusiastic criticisms that have been leveled against personality traits in general. The other issue concerns the empirical investigation of affect or mood states.

Mischel (1968), probably the most cited spokesman in what has been called the situationalism controversy, argued that insufficient evidence exists to support either the temporal stability of trait measures or the situational generality of behaviors supposedly under the control of these traits. There is not room here to summarize the voluminous literature dealing with these issues, but comprehensive reviews are available elsewhere (e.g., Bowers, 1973; Mischel, 1973). We focus on only one outcome of the protracted discussion here. At the same time, we concentrate on the notion of temporal stability, for we believe it to be the more basic of the two issues.

The situationalism debate has led, not to an abandonment of interest in individual differences, but to a wider recognition of the need to modify the way personality research is conceptualized and executed. Currently, a major theme of this remodeling effort has focused on providing room for the influence of situational factors as they interact with personality characteristics to determine behavior (Mischel, 1973). Three activities which seem central to the interactionist position are the following: (a) isolating important attributes of persons and situations; (b) discovering how the attributes are organized within persons and situations, respectively; and (c) generating a theoretical account of how such configurations of attributes interact in determining behavioral outcomes. One implication is that the development of a reliable and parsimonious taxonomy of human attributes, and one of situations, remains the first task of the day. Success in generating a more complete account of behavior will, of logical necessity, rest on the

quality of the components in the respective taxonomies. Whether the factor-analytic model is a fruitful way to generate these taxonomies is an empirical question. There is no reason to believe, however, that it should be excluded from what should undoubtedly be a multifaceted attack on an obdurate problem.

Perhaps the reader is asking why some researchers believe that factor analysis, in the past, contributed more to the problem than to its solution. Part of the answer to this question was provided by J. L. Horn and Little (1966) who noted that, primarily as a historical accident, trait theorists tended to assume rather than study the temporal stability of their measures. In other words, influential researchers who used factor-analytic methods placed unwarranted confidence in *R*-technique analysis as a means for isolating trait dimensions. Realizing that either trait or state factors can emerge from such an analysis, it is reasonable to suspect that existing measuring instruments possibly confound these two sources of variance. Although it is indirect and was mentioned earlier, some empirical support for this speculation may be found in the work of Hundleby, Pawlik, and Cattell (1965) who, in summarizing some 25 years' research, called attention to a general parallelism between the loading patterns produced by *R* technique and those produced by *dR* analyses. Such cross-technique matching of loading patterns is open to a number of interpretations (e.g., all resulting factors could be of the cell *b* variety) and carefully designed investigations are needed to resolve the ambiguity. Perhaps for some dimensions the investigatory process might result in a disentanglement of trait and state factors. Trait dimensions thus refined might provide the basis for developing the taxonomies mentioned above.

A disentanglement of trait and state has

been proceeding in the area of anxiety for some time and merits brief attention here. Stimulated by the earlier work of Cattell and Scheier (1961), Spielberger (1966) suggested that much of the conceptual confusion and equivocal research findings that characterize the field stem from the failure to distinguish between trait and state anxiety and the use of measures that confound these two concepts. Subsequent work in this area was concerned with empirically showing a distinction between trait and state anxiety and with establishing their construct validity. Two studies reported here provide examples of how the factor-analytic techniques advocated in this chapter have been used to discriminate state from trait dimensions in the area of anxiety.

To demonstrate that trait and state anxiety exist as measurably distinct concepts, Cable (1972; Nesselroade & Cable, 1974) administered a questionnaire battery on two occasions, separated by a brief interval, to a group of college students. The measures included items from a trait-state anxiety battery under development and a similar instrument constructed by Spielberger, Gorsuch, and Lushene (1969). A single analysis was performed on the product moment correlations derived from data pooled over both occasions of measurement. This procedure forces the factor-loading pattern to be invariant (see section 6) and permits an inspection of factor score stabilities under that constraint. Final loading patterns of the two factors that were extracted and rotated to an oblique simple structure solution are presented in Table 1. In relation to the trait-state distinction, the variables show a strikingly consistent and supportive cleavage onto two factors. The theoretical distinction required that these dimensions also manifest differential levels of stability. When test-retest stability coefficients were calculated, using estimated factor scores,

TABLE 1 Loading pattern of trait and state anxiety measures

Variable ^b	Factor ^a	
	I (State anxiety)	II (Trait anxiety)
1. State anxiety (S)	.93	-.05
2. State anxiety (S)	.99	-.13
3. State anxiety (CN)	.76	.13
4. State anxiety (CN)	.77	.06
5. Trait anxiety (CN)	-.01	.74
6. Trait anxiety (CN)	-.13	.86
7. Trait anxiety (S)	.08	.84
8. Trait anxiety (S)	.10	.81

Note. After Cable, 1972.

^aFactor intercorrelation = .70.

^bS signifies that a variable is a subset of items from the State-Trait Anxiety Inventory (Spielberger, Gorsuch, & Lushene, 1969); CN that a variable is a subset of items from an experimental state-trait battery under development by Cattell and Nesselroade.

they were found to be .68 for the state and .93 for the trait. An examination of average internal consistency reliability coefficients of the scales (about .81 for the state and .72 for the trait) indicated that the theoretically correct, discrepant stabilities of the two factors were not due to differential reliabilities of the measures.

To investigate the effect of various instructions both on the invariance of factor loadings and on the stability of factor scores, Bartsch (1976) used a design similar to that of Cable (1972) and incorporated manipulations hypothesized to alter the level of self-reported anxiety state but to leave unaltered that of self-reported trait anxiety. Factoring each occasion of data separately, Bartsch found a similarly consistent division of trait and state measures onto separate factors and, moreover, that whereas state factor scores were appropriately modulated, the trait factor scores were as appropriately impervious to the experimental manipulations. Bartsch (1976) included in his analysis measures of height, weight, and sex of subjects to define a third factor that would

permit comparisons between physical and psychological dimensions on both factor-loading pattern invariance and temporal stability of factor scores. The comparisons, summarized in Table 2, showed that all factors exhibited high temporal invariance but differential stabilities, as demanded by the theoretical expectations.

Investigations such as those of Bartsch (1976) and Cable (1972) demonstrate in a concrete fashion how the proposed techniques vastly extend the scope of factor analytic research. In addition, the studies reveal how information gained by the employment

TABLE 2 Comparison of temporal invariance (by congruence coefficient) and stability levels between three R-technique factors

Factor	Coefficient	
	Congruence	Stability
State anxiety	.971	.709
Trait anxiety	.958	.862
Sex, body size	.931	.982

Note. After Bartsch, 1972.

of these methods may lead to a more accurate definition of personality trait and state dimensions. The Bartsch study especially, shows how functional relationships may be examined through the inclusion of experimentally manipulated variables. Such precise definition and the provision for situational manipulations seems vital to any subsequent attempt to articulate further the interactionist model.

The study of rapid and reversible changes such as emotional responses is an area that could benefit significantly from improved multivariate methodology. Cattell (1973a) pointed out that several major attempts to construct scales (Gottschalk & Gleser, 1969; Zuckerman, 1960) relied on clinical or rational criteria, with the result that too little is known about the structural composition of the measures. Other researchers (McNair & Lorr, 1964; Nowlis & Green, 1965) made use of factor-analytic procedures but tended to rely on single-occasion, *R*-technique strategies which, as was pointed out earlier, do not yield any information on the temporal stability of the resulting dimensions.

One desirable step in light of the critical review of Luborsky and Mintz (1972)—the assessment simultaneously of invariance and stability in the mood domain—was undertaken by Lebo (1972). *P*-technique data from five pregnant subjects were factor analyzed; and Lebo, with the help of various factor rotation procedures, defined several general patterns of mood change during prepartum and postpartum intervals.

One of the most systematic and comprehensive attempts to structure intraindividual variability by multivariate procedures has been the series of *P*- and *dR*-technique studies conducted over a period of many years by Cattell and various co-workers. The work has been summarized (Cattell, 1973a; Cattell & Scheier, 1961) and numerous implications of the research findings for

prediction models, measurement procedures, and personality theory in general have been discussed. Researchers interested in trying to embrace personality in the broad sense can no longer afford to ignore the substantive and methodological issues that work on states has called to our attention.

8 SUMMARY

1. Concepts of change are of central importance to the study of behavior. Change concepts must be tied to explicit, rigorous measurement and analysis operations if they are to make a significant contribution to the integration of data and theory in this area.
2. In deriving a set of change constructs from empirical data, multivariate analysis procedures permit the investigation of a multitude of variables, all changing simultaneously, rather than the study of one or two variables in relative isolation. Determination of invariant, replicable dimensions of change underlying observed intraindividual variation may well account for some of the gaps now current in essentially trait-oriented systems.
3. Various writers argued that the covariance of two or more measures on a given entity over occasions is a necessary and sufficient condition for inferring that they are measures of the same thing. *P*-technique factor analysis, one method of structuring intraindividual variability, takes this inference as a starting point and then proceeds to determine the number and nature of such underlying sources of variation. It precludes sources of interindividual variation by using only one person as a data source.
4. Two major problem areas encountered in dealing with change are (a) questions of measuring and scaling change data per se and (b) the development and use of models by which to explore change structure. Many of the current procedures attempting to deal with the second problem involve variations

of one kind or another on the basic factor-analytic concepts. These are proving invaluable aids in bringing order into a complex, chaotic domain.

5. The linear specification equation of factor analysis can be defined to include both dimensions of interindividual and intraindividual variation. Thus the two may be brought into a common framework, and the useful information of both may be used to predict behavior. By various analytical techniques it may be possible to split up these two kinds of factors for further study and experimentation.

6. Substantive researchers can use the powerful factor-analytic model in a variety of ways to study the distinction between personality states and traits. Focusing on two major characteristics of factors—invariance of loading patterns and stability of factor scores—an investigator may proceed to establish parametric values for different substantive dimensions of interest, or he may introduce invariance or stability directly

to defining characteristics of a factor. In many situations, factor models and manipulative experimentation can and should be combined to provide potentially fruitful research designs.

7. The ultimate usefulness of personality traits as a basis for developing a science of behavior has been seriously questioned by numerous psychologists. Alternative formulations include situationalism which, vis-a-vis trait theory, seems to miss the mark as widely on the other side, and a more temperate person-by-situation interactionist position. Further elaboration of the latter depends to a large extent on one's ability to dimensionalize precisely and exhaustively both person and situation characteristics. Refined application of various factor-analytic research designs and multivariate concepts such as the distinction between traits and states potentially offers valuable help in more carefully exploring the general theoretical worth of the interactionist approach.