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States and Traits in Psychological Assessment

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The person-situation debate has made clear that not only errors of measurement but also situational effects and effects of the interaction between persons and situations contaminate psychological assessments of traits. In this paper, a solution to this problem is proposed. Supplementing traditional ANOVA methods for experimental person-situation research, our approach is applicable in purely observational studies. It is based on a general theory defining (a) states and traits, and (b) consistency, occasion specificity, reliability, and stability coefficients. This theory relies on two decompositions: (a) the decomposition of any observed score into a latent state and a measurement error component, and (b) the decomposition of any latent state into a latent trait and a latent state residual. This conceptualizes more precisely the widely accepted view that most psychological attributes have both state and trait components. Several sets of assumptions are presented which lead to different simultaneous equation models. States and traits are simultaneously represented as latent variables in these models. Examples from research on anxiety and coping illustrate how to estimate parameters, test hypotheses, and evaluate model fit by widely used computer programs.

The description and explanation of stability and change in human behavior are basic tasks of psychological theory and *psychological assessment.* Any psychological attribute may be described with respect to *at least* two sources of variability: (a) interindividual differences and (b) intraindividual differences (or changes). Traditional disciplines of psychology are interested primarily in only *one* of these sources of behavioral variability (Cronbach, 1957). Differential Psychology focusses on the variability between persons, i.e., *inter*individual differences. General Psychology (e.g., learning, perception), Social Psychology, and (General) Developmental Psychology aim at the description and explanation of behavioral differences between situations and times, i.e., *intra*individual variability. Each of these perspectives considers other sources of variance less important or less interesting for the explanation of behavior.

The emphasis on only one particular source of behavioral variability is evidenced by the different research designs chosen and *assessment strategies* used. Trait theorists, on one side, are advised to observe the same individuals at several occasions in order to reduce occasion specific variation (due to situational differences) in psychological measures via aggregation. Situationists, on the other side, try to maximize behavioral variance determined by situations via experimental manipulation.

The shortcomings of each of these perspectives (Cronbach, 1975) are obvious and have led scholars to develop conceptual models, research designs, and assessment strategies that incorporate more than one factor of behavioral variability (e.g., Buss, 1979; Cattell, 1966; Ozer, 1986). *Modern Interactionism* (cf. Bowers, 1973; Endler & Hunt, 1966; Sarason, Smith, & Diener, 1975) as well as research on aptitude-treatment interactions (e.g., Cronbach & Snow, 1977), for instance, have used ANOVA designs to investigate how much of behavioral variability is due (a) to individual differences, (b) to differences between situations, and (c) to interactions between persons, situations, and response modes.

State-trait theories address the same kind of questions (Cattell, Cattell, & Rhymer 1947; Cattell & Scheier, 1961). Just like interactionists, state-trait theorists acknowledge the existence of stable individual differences *and* intraindivual changes in psychological attributes. Research on the state-trait distinction has aimed at demonstrating that state measures are less stable than trait measures although their reliabilities do not differ (Zuckerman, 1983).

If we concede that each observed psychological attribute is affected to some degree by characteristics of the individual, situational and/or interactional influences, as well as measurement error, we implicitly decompose an observed measurement into:

1. a component that is free of situational and/or interactional effects,
2. a situational and/or interactional component, and
3. a measurement error.

We suggest to call the first component the "trait" and the sum of (1) and (2) the "state". One might prefer other names for this distinction, but the distinction itself is necessary as soon as we accept the existence of situational and/or interactional effects.

The existence of situational and/or interactional effects on any kind of behavior has important implications for *psychological assessment*. The development and application of measurement instruments requires knowledge not only about their reliability but also about the extent to which they measure stable characteristics of the person, i.e., traits, and transient effects of the situational and organismic context in which the measure is taken. *Trait measures* should be affected as little as possible by occasion-specific effects, whereas *state measures* should be as sensitive as possible to such transient influences.

Traditional Approaches to the State-Trait Distinction

Operational Approaches

Let us consider Spielberger's (e.g., 1972) proposal for the assessment of states and traits. Spielberger (1972, p. 31) gives the following characterizations of states and traits:

"Personality states may be regarded as temporal cross sections in the stream-of-life of a person (Thorne, 1966). A personality state exists at a given moment of time, and at a particular level of intensity. Although personality states are often transitory, they can recur when evoked by appropriate stimuli, and they may endure over time when the evoking conditions persist. Emotional reactions may be viewed as expressions of personality states. ... In contrast to the transitory nature of personality states, personality traits may be conceptualized as relatively enduring individual differences among people in specifiable tendencies to perceive the world in a certain way and/or in dispositions to react or behave in a specified manner with predictable regularity. ... The stronger a particular personality trait, the more probable it is that an individual will experience the emotional state that corresponds to this trait, and the greater the probability that behaviors associated with the trait will be manifested in a variety of situations."

In order to relate these theoretical ideas to empirical research, Spielberger operationalizes states and traits simply by using different instructions in his questionnaires: For the measurement of states people are asked to rate how they feel "right now", whereas for the assessment of traits people have to rate how they feel "in general". Yet how can we know that this instruction works, i.e., how can we know that there are no situational effects on the answers to the items in the trait inventory? And, if there are situational effects, what is the relation between the scores on the trait scales and the trait itself? And conversely, how much, if at all, do the state measures depend on the trait? What is the relation between states and traits?

Autocorrelational Approaches

A common solution for answering these questions is to investigate empirically the longitudinal stability of the scale scores of state-trait questionnaires. A sophisticated version of this strategy has been presented by Hertzog and Nesselroade (1987). Their approach is based on latent variable simultaneous equation modeling.

Hertzog and Nesselroade characterize traits as "attributes of individuals that are relatively stable across occasions. States, on the other hand, comprise attributes of individuals that are relatively changeable in nature" (p. 95). Traits, "because of their putative stability, are potentially useful for the purpose of discriminating between one individual and another without having to consider intraindividual change" (p. 95).

This formulation suggests that a trait is defined such that each individual is assigned *one and only one* value with respect to this trait, the individual's trait score. Strictly taken, this would imply perfect stability of traits across occasions of measurement. However, Hertzog and Nesselroade allow for changes in a trait by stating that it "will remain the same unless and until organismic or environmental influences act to change it" (p. 95).

States, according to Hertzog and Nesselroade "most commonly represent dimensions of intraindividual change and serve to discriminate one time or situation in the life of a person from another" (p. 95). This suggests that each individual is assigned *one value for each occasion* with respect to the attribute considered. Since change between occasions is not excluded for traits, however, the question arises what makes the differences between changing traits and states. Is there only a gradual difference between these two concepts? And if so, where is the cut-point?

Hertzog and Nesselroade's opinion on this problem reads: "Generally it is certainly the case that most psychological attributes will neither be, strictly speaking, traits or states. That is, attributes can have both trait and state components" (p. 95). We believe that this is a core issue in the state-trait distinction. However, the postulate that *each psychological attribute comprises of both trait and state components* does not show up in the statistical models suggested by Hertzog and Nesselroade. Their solution for the distinction of traits and states relies on the *size of the autocorrelations* of latent trait and latent state variables: they are expected to be high in the case of traits and low in the case of states. Again, we are confronted with the problem where to set a cutpoint that splits autocorrelations into high and low, and latent variables into traits and states, respectively.

Although we share the intuitions about the state-trait distinction reviewed above, we aim at elaborating a more precise definition of states and traits. The distinction we propose more closely relates theory to empirical data and incorporates the basic idea that each psychological attribute comprises both, trait and state components.

The organisation of this paper is as follows: First, we present a general definition of states and traits and describe their relations to the coefficients of consistency, occasion specificity, and reliability. In the second part, assumptions are introduced that lead to special simultaneous equations models. In the third and last part, these models are illustrated by empirical examples from research on anxiety and coping.

General Latent State-Trait Theory

It will be useful to introduce General Latent State-Trait Theory (General LST Theory) with a brief review of the basic concepts of Classical Test Theory (CTT). An appropriate generalization of CTT will then be developed which allows to unambiguously define latent state and trait variables. The variances and covariances of the latent state and trait variables will then be related to concepts such as consistency, occasion specificity, reliability, and stability. Note that we do not introduce any *assumptions* in this section. Instead we only present a conceptual framework (or "architecture") which systematically relates to each other the concepts mentioned above. This means that the concepts and their properties presented in this section "cannot be disproved by any set of data" (Lord, 1980, p. 6). Hence, the applicability of these concepts is *not* conditional on the validity of any assumptions (except for the trivial and nonrestrictive assumption that the variances of the observed Y variables are finite and greater than zero).

Basic Concepts of Classical Test Theory

In Classical Test Theory (Gulliksen, 1950; Lord & Novick, 1968; Zimmerman, 1975) we consider the following type of random experiments: A unit u (e.g., a person) is drawn from a set U of observational units and the values of u with respect to several attributes (e.g., answers to items of a questionnaire) are observed. Hence, the set of possible outcomes of this kind of random experiment is:

$$\Omega = U \times M, \qquad (1)$$

where M might be a product set $\Omega_1 \times \ldots \times \Omega_m$, for instance, representing the possible results of answering the m items of a questionnaire (for more details, see Steyer, 1989). Furthermore, there are numerical random variables $Y_i: \Omega \rightarrow \mathbb{R}$, $i = 1, \ldots, m$, (e.g., the test score variables) and the mapping $p_U: \Omega \rightarrow U$, the values of which are the observational units $u \in U$ (e.g., persons).

The *truescore variables* τ_i, $i = 1, \ldots, m$, are defined

$$\tau_i := E(Y_i \mid p_U), \qquad (2)$$

where $E(Y_i \mid p_U)$ denotes the conditional expectations (see, e.g., Bauer, 1981, p. 312, or Feller, 1971, p. 164) of the variable Y_i given p_U. The values of $E(Y_i \mid p_U)$ are the conditional expected values $E(Y_i \mid p_U{=}u)$ or the *true scores* of the observational units (persons) u. The error variables ε_i, $i = 1, \ldots, m$, are defined

$$\varepsilon_i := Y_i - E(Y_i \mid p_U),$$

and the *reliability coefficients* $Rel(Y_i)$, $i = 1, \ldots, m$,

$$Rel(Y_i) := Var[E(Y_i \mid p_U)]/Var(Y_i) = Var(\tau_i)/Var(Y_i). \qquad (4)$$

The definitions of the true score variables and error variables above imply – among others – the following equations for $i, j = 1, \ldots, m$:

$$Y_i = \tau_i + \varepsilon_i, \qquad (5)$$

$$E(\varepsilon_i) = 0, \qquad (6)$$

$$E(\varepsilon_i \mid p_U) = 0, \qquad (7)$$

$$E(\epsilon_i \mid \tau_j) = 0, \tag{8}$$

$$Cov(\tau_i, \epsilon_j) = 0, \tag{9}$$

$$Var(Y_i) = Var(\tau_i) + Var(\epsilon_i), \tag{10}$$

(see Steyer, 1989, or Zimmerman, 1975, for a more complete list of properties of the error variables). Noncorrelation of the error variables, $Cov(\epsilon_i, \epsilon_j) = 0, i \neq j$, does not follow from the definitions of τ_i and ϵ_i, whereas $Cov(\tau_i, \epsilon_j) = 0$, for instance, does follow.

Basic Concepts of General Latent State-Trait Theory

The basic idea of the *generalization* of the classical concepts described above is to consider *n* occasions of measurement and to reinterpret the set *U* of observational units as a cartesian set product

$$U = U_0 \times U_1 \times \ldots \times U_n \tag{11}$$

of a set U_0 of persons and sets U_k of situations that may occur on occasion *k* of measurement, $k = 1, \ldots, n$. (For other interpretations of *U* see Steyer & Schmitt, 1990a). This reinterpretation reflects the fact that measurement does not take place in a situational vacuum; a person can be measured only in a situation which might have a systematic effect on each variable measured on occasion *k*. In other words, the observational units are not persons but persons-in-a-situation (Anastasi, 1983; Magnusson, 1984). Hence, for *n* occasions of measurement, the set of possible outcomes of this kind of random experiment is:

$$\Omega = (U_1 \times \ldots \times U_n) \times (M_1 \times \ldots \times M_n). \tag{12}$$

Any possible outcome of this type of experiment is an $(1 + 2n)$-tupel consisting of an element of U_0 (a person), one element of each U_k, $k = 1, \ldots, n$ (a situation occurring on occasion *k*), one element of each M_k (a combination of attributes of the person-in-the-situation on occasion *k*). For instance, if ten items are administered on occasion *k*, an element of M_k might consist of the scores of the person with respect to these ten items.

We may now consider the mapping $p_0\colon \Omega \rightarrow U_0$, the values of which are the persons. The value of the mapping $p_k\colon \Omega \rightarrow U_k$, $k = 1, \ldots, n$, is the situation in which the person is measured on the *k*th occasion. The situations do *not* have to be known. We only presume that it is reasonable to assume that a (usually unknown) situation occurs each time a person is measured. Hence, this approach may be applied in purely observational studies involving at least two occasions of measurement. This approach differs from the ANOVA type models used in modern interactionism, because there, several individuals are exposed to the same situation.

The test score variables within each occasion *k* are denoted $Y_{1k}, \ldots, Y_{m_k k}$, *the first index indicating the i*th variable observed on occasion *k*. Hence, m_k is the number of *Y* variables observed on occasion *k*. Within this conceptual framework we may now consider not only the conditional expectations $E(Y_{ik} \mid p_0, p_k)$, but also $E(Y_{ik} \mid p_0)$ and $E(Y_{ik} \mid p_k)$. Considering $E(Y_{ik} \mid p_0, p_k)$, we condition on persons *and* situations, whereas conditioning is on persons or situations in $E(Y_{ik} \mid p_0)$ and $E(Y_{ik} \mid p_k)$, respectively. These conditional expectations are *random variables* because persons and situations are sampled randomly, that is, according to some (usually unknown and unspecified) distribution. The values of $E(Y_{ik} \mid p_0, p_k)$ are the conditional expectations $E(Y_{ik} \mid p_0{=}u_0, p_k{=}u_k)$ of the variable Y_{ik} given the person u_0 in the situation u_k.

If we define the *latent state variables*

$$\tau_{ik} := E(Y_{ik} \mid p_0, p_k), \tag{13}$$

which pertain to the *k*th occasion of measurement, and *the error variables*

$$\epsilon_{ik} := Y_{ik} - E(Y_{ik} \mid p_0, p_k), \tag{14}$$

we have the (mathematically trivial) *basic decomposition*

$$Y_{ik} = \tau_{ik} \qquad\qquad + \epsilon_{ik} \tag{15}$$

$$= E(Y_{ik} \mid p_0) + [E(Y_{ik} \mid p_0, p_k) - E(Y_{ik} \mid p_0)] + \epsilon_{ik} \tag{16}$$

$$= \xi_{ik} \qquad + \zeta_{ik} \qquad + \epsilon_{ik} \tag{17}$$

where $\xi_{ik} := E(Y_{ik} \mid p_0)$, $\tau_{ik} := E(Y_{ik} \mid p_0, p_k)$, and $\zeta_{ik} := E(Y_{ik} \mid p_0, p_k) - E(Y_{ik} \mid p_0)$. We now call τ_{ik} the *latent state variable*, ξ_{ik} the *latent trait variable*, and ζ_{ik} the *latent state residual*. All of these three latent variables are defined with respect to the observed variables Y_{ik}. Figure 1 shows how these variables are related to each other.

The definition $\xi_{ik} := E(Y_{ik} \mid p_0)$ makes clear that the values of a latent trait variable ξ_{ik} characterize a person; each person u_0 is assigned one and only one score of ξ_{ik}, the conditional expected value $E(Y_{ik} \mid p_0{=}u_0)$. In contrast, the definition $\tau_{ik} := E(Y_{ik} \mid p_0, p_k)$ shows that a latent state variable τ_{ik} characterizes a person-in-the-situation (u_0, u_k); each *person-in-the-situation* is assigned one and only one score of τ_{ik}, the conditional expected value $E(Y_{ik} \mid p_0{=}u_0, p_k{=}u_k)$. Finally, the definition $\zeta_{ik} := E(Y_{ik} \mid p_0, p_k) - E(Y_{ik} \mid p_0)$ implies that the latent state-trait residual ζ_{ik} also characterizes the person-in-the-situation, because each (u_0, u_k) is assigned one and only one score of ζ_{ik}, the difference $E(Y_{ik} \mid p_0{=}u_0, p_k{=}u_k) - E(Y_{ik} \mid p_0{=}u_0)$.

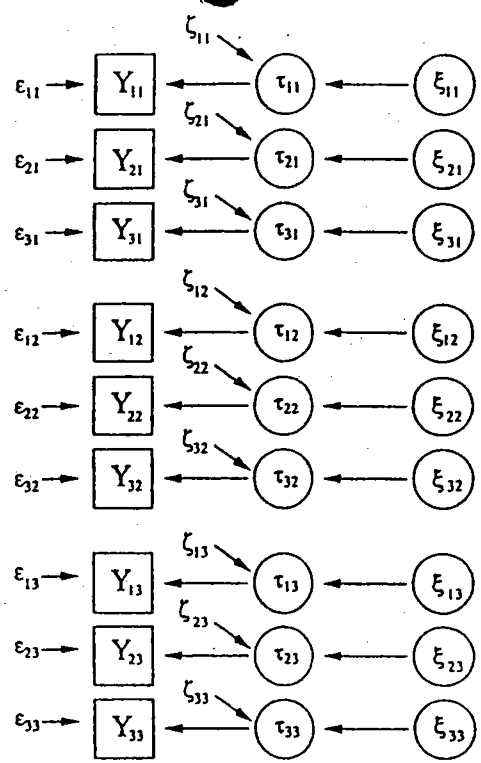

Figure 1. Path diagram representing the basic decomposition of each Y_{ik}. All variables are correlated with each other except for those mentioned in Equations 28 and 29. To avoid information overload, these correlations are not symbolized in the figure.

Note that ζ_{ik} can also be written

$$\zeta_{ik} = E(Y_{ik} \mid p_0, p_k) - E(Y_{ik} \mid p_0) \tag{18}$$

$$= E(Y_{ik} \mid p_k) + [E(Y_{ik} \mid p_0, p_k) - E(Y_{ik} \mid p_0) - E(Y_{ik} \mid p_k)], \tag{19}$$

(situation effect) + [interaction effect]

which shows that ζ_{ik} consists of a situational and an interactional effect. The definitions of the latent variables are summarized in Part A of Table 1.

Table 1. Basic Concepts of General Latent State-Trait Theory

A. Definition of Basic Variables	
$\tau_{ik} := E(Y_{ik} \mid p_0, p_k)$	Latent State Variables
$\xi_{ik} := E(Y_{ik} \mid p_0)$	Latent Trait Variables
$\zeta_{ik} = \tau_{ik} - \xi_{ik}$	Latent State Residuals
$\epsilon_{ik} = Y_{ik} - \tau_{ik}$	Measurement Error Variables
B. Decompositions of Variables and Variances	
$Y_{ik} = \tau_{ik} + \epsilon_{ik}$	
$\tau_{ik} = \xi_{ik} + \zeta_{ik}$	
$Var(Y_{ik}) = Var(\tau_{ik}) + Var(\epsilon_{ik})$	
$Var(\tau_{ik}) = Var(\xi_{ik}) + Var(\zeta_{ik})$	
C. Other Basic Properties	
$E(\epsilon_{ik}) = E(\zeta_{ik}) = 0$	
$Cov(\epsilon_{ik}, \zeta_{jk}) = Cov(\epsilon_{ik}, \tau_{jk}) = Cov(\epsilon_{ik}, \xi_{jl}) = Cov(\zeta_{ik}, \xi_{jl}) = 0$	
D. Important Parameters	
$Rel(Y_{ik}) = Var(\tau_{ik}) / Var(Y_{ik})$	Reliability
$= Con(Y_{ik}) + Spe(Y_{ik})$, where	
$Con(Y_{ik}) = Var(\xi_{ik}) / Var(Y_{ik})$	Consistency
$Spe(Y_{ik}) = Var(\zeta_{ik}) / Var(Y_{ik})$	Occasion Specificity
$Cor(\tau_{ik}, \tau_{il}),\ k \neq l$	Stability of States
$Cor(\xi_{ik}, \xi_{il}),\ k \neq l$	Stability of Traits

Note: $Cor(\xi_{ik}, \xi_{il})$ denotes the correlation between two latent trait variables with identical first indices but pertaining to two different occasions. All properties listed in this table (including the decompositions of variances) follow from the definitions of τ_{ik}, ξ_{ik}, ϵ_{ik}, and ζ_{ik} (see Steyer & Schmitt, 1990). There are no assumptions other than that the variances of the variables Y_{ik} are finite and greater than zero. All equations displayed hold for all $i, j \in I_k := \{1, \ldots, m_k\}$ and $k, l \in K := \{1, \ldots, n\}$, where m_k is the number of variables measured on occasion *k* and *n* is the number of occasions of measurement.

Equations 13 to 17 clarify what it might mean that attributes (the *Y* variables) "can have both trait and state components" (Hertzog & Nesselroade, 1987, p. 95). According to Equation 15, $Y_{ik} = \tau_{ik} + \epsilon_{ik}$, that is, Y_{ik} is decomposed into its latent state component τ_{ik} and an error variable ϵ_{ik}. Furthermore, some algebra yields

$$\tau_{ik} = \xi_{ik} + \zeta_{ik}. \tag{20}$$

Hence the latent state variable τ_{ik} itself is decomposed into the latent trait component ξ_{ik} and the latent state residual ζ_{ik}. The conjunction of Equations 17 and 20 reveal how the quotation cited above may be formulated more precisely: Manifest attributes (Y variables) have an error and a (latent) state component, and the state component itself consists of a trait component and a residual that is not determined by the trait but by the specific situations present at the occasion of measurement considered and/or by the interactions between persons and those situations.

Furthermore, we may now better understand Hertzog and Nesselroade's assertion that states "most commonly represent dimensions of intraindividual change and serve to discriminate one time or situation in the life of a person from another" (1987, p. 95). In fact, the score on the latent state variable τ_{ik} referring to occasion k of measurement not only depends on the person but also on the situation in which the person is measured on that occasion. In contrast, a score on the latent trait variable ξ_{ik} only depends on the person but not on the situation in which the person is measured on that occasion (see the definition of ξ_{ik}).

Note, however, that the score of a person on ξ_{ik} may differ from his or her score on ξ_{il} for different occasions k and l of measurement. Assumptions on different kinds of stability (such as $\xi_{ik} = \xi_{il}$ or $\xi_{il} = \alpha_{ilk} + \beta_{ilk} \cdot \xi_{ik}$, where α_{ilk} and β_{ilk} are real numbers) may be introduced in special models. However, if no further assumptions are introduced, trait scores possibly change between occasions of measurement although – by definition – they are not affected by the situation present at the occasion of measurement. A change of traits between different occasions of measurement may be due to genetically determined change, learning, or critical life events between occasions of measurement, for instance. This makes clear that the state-trait distinction does not logically imply that traits are innate or unchangeable. In Hertzog and Nesselroade's terms, a trait "need not be construed as connoting immutable, genetically determined behavioral dispositions" (p. 95).

Consistency, Occasion Specificity, Reliability, and Stability

Hertzog and Nesselroade (1987) hint at the "conceptual confusion of *stability* and *reliability*" and at the common misconception that "fluctuant attributes have little predictive validity or explanatory power" (p. 95). This, too, is well in line with our conceptual framework. However, aside from the differentiation between reliability and stability, we add the distinction between *consistency* and *occasion specificity*. These concepts may now be formally defined in terms of the latent state and trait variables introduced above.

Before we define these concepts, we want to point out again that the variances of the variables ξ_{ik}, ζ_{ik}, and ε_{ik} add up to the variance of Y_{ik}, *without any additional assumptions* other than that the variances of the Y variables are finite:

$$Var(Y_{ik}) = Var(\xi_{ik}) + Var(\zeta_{ik}) + Var(\varepsilon_{ik}). \quad (21)$$

Furthermore,

$$Var(\tau_{ik}) = Var(\xi_{ik}) + Var(\zeta_{ik}). \quad (22)$$

The additivity of these variances has been derived by Tack (1980; see also Steyer & Schmitt, 1990a). If $Var(Y_{ik})$ is greater than zero, the last two equations allow us to define

$$Rel(Y_{ik}) := Var(\tau_{ik})/Var(Y_{ik}), \quad (23)$$

$$Con(Y_{ik}) := Var(\xi_{ik})/Var(Y_{ik}), \quad (24)$$

$$Spe(Y_{ik}) := Var(\zeta_{ik})/Var(Y_{ik}), \quad (25)$$

to be the *coefficients of reliability, consistency*, and *occasion specificity*, respectively. Additionally, we may define the correlation $Cor(\tau_{ik}, \tau_{il})$ to be the *stability of the latent state variables* and $Cor(\xi_{ik}, \xi_{il})$ to be the *stability of the latent trait variables* between occasions k and l.

The use of the word "stability" in this context presumes that τ_{ik} and τ_{il} (ξ_{ik} and ξ_{il}) represent the "same states" ("same traits") in some sense to be specified. For instance, using the same index i might indicate that the same test is given on the two occasions k and l. However, in some applications, a parallel form might do as well. If this assumption does not hold, one should simply use the term "correlation" (e.g., between τ_{ik} and τ_{il}) instead of the term "stability".

Because of Equation 22,

$$Rel(Y_{ik}) = Con(Y_{ik}) + Spe(Y_{ik}), \quad (26)$$

i.e., consistency and occasion specificity add up to the reliability coefficient. The coefficients $Con(Y_{ik})$ are the proportions of variance reflecting the interindividual differences that are not due to the different situations in which the persons are measured on occasion k. The coefficients $Spe(Y_{ik})$ are the proportions of variance due to the situations and/or the

person-situation interactions (see Equation 19) on occasion k.

The following equations describe the most important properties of the variables defined in Equation 13 to 17. For $i, j \in I_k := \{1, \ldots, m_k\}$ and occasions $k, l \in K := \{1, \ldots, n\}$:

$$E(\varepsilon_{ik}) = E(\zeta_{ik}) = 0, \quad (27)$$

$$Cov(\zeta_{ik}, \varepsilon_{jk}) = Cov(\tau_{ik}, \varepsilon_{jk}) = 0, \quad (28)$$

$$Cov(\xi_{ik}, \zeta_{jl}) = Cov(\xi_{ik}, \varepsilon_{jl}) = 0. \quad (29)$$

Whereas Equation 28 refers to covariances *within* each occasion k, Equation 29 also refers to covariances *across* occasions. Note that these equations are not assumptions. Instead, they are consequences of the definitions of the variables ξ_{ik}, τ_{ik}, ζ_{ik}, and ε_{ik} (see Steyer & Schmitt, 1990a). Just like the corresponding properties of Classical Test Theory (see Equations 5 to 10), *they cannot be wrong in empirical applications*. Just like the statement "a bachelor is unmarried" cannot be wrong, they are logical consequences of the definitions of the variables involved. One might refuse to use the definitions; once the definitions are used, however, Equations 27 to 29 are necessarily true.

To summarize, in the context of General Latent State-Trait Theory, we differentiate between five basic concepts: *Reliability* is the proportion of variance of the observed variable Y_{ik} due to the latent state variable τ_{ik}. Consistency is the proportion of variance of the observed variable Y_{ik} due to the latent *trait* variable ξ_{ik}. *Occasion specificity*, which represents the proportion of variance due to the situational and/or interactional effects, is the difference between reliability and consistency. *Stability of the latent state variables* is the correlation between latent *state* variables of different occasions of measurement having identical first indices. *Stability of the latent trait variables* is the correlation between latent *trait* variables of different occasions of measurement having identical first indices. Table 1 summarizes these concepts and their relation to latent states and traits.

Latent State-Trait Models

The number of latent variables occurring in Figure 1 and their correlations make clear that assumptions have to be introduced in order to be able to identify the variances and covariances of these latent variables. In this section we will present and discuss five classes of models that may be formulated within the conceptual framework presented above.

Latent Trait (LT) Models

The traditional way to solve the problem of measurement error is to define a trait to be the factor (or *latent trait*) in a model of congeneric variables. The set of assumptions constituting this class of models is presented in Table 2 (for a more formal presentation and references, see Steyer, 1989). All Y variables measure the same latent trait (congenerity) and all ε variables are uncorrelated among each other (uncorrelated errors). Submodels result from restricting the coefficients and the variances of the ε_{ik} to be equal for different variables Y_{ik}.

Table 2. Assumptions and Some Consequences of the Latent Trait Model.

Assumptions		
(a)	$Y_{ik} = \tau_{ik} + \varepsilon_{ik} = \xi_{ik} + \varepsilon_{ik} = \alpha_{ik} + \lambda_{ik}\,\xi + \varepsilon_{ik}$, where $E(\varepsilon_{ik} \mid p_0, p_k) = 0$, and $\alpha_{ik}, \lambda_{ik} \in \mathbb{R}$	Congenerity
(b)	$Cov(\varepsilon_{ik}, \varepsilon_{jl}) = 0, \quad (i, k) \neq (j, l)$,	Uncorrelated Errors
Consequences of the Assumptions		
(1)	$Var(\tau_{ik}) = Var(\xi_{ik}) = \lambda_{ik}^2\, Var(\xi)$	Variances of Latent States and Latent Traits
(2)	$Con(Y_{ik}) = Rel(Y_{ik}) = \dfrac{\lambda_{ik}^2\, Var(\xi)}{Var(Y_{ik})}$	Consistency and Reliability

Note: Those consequences are listed which relate the LST theoretical parameters (left side of the equations) to the parameters of the model defined by the assumptions listed in this table. The equations hold for all $i, j \in I_k := \{1, \ldots, m_k\}$ and $k, l \in K := \{1, \ldots, n\}$, where m_k is the number of variables measured on occasion k and n is the number of occasions of measurement.

This class of models, which may also be called *single-trait models*, might be desirable for the pure trait theorist. However, these models ignore the problem of occasion specificity, because situational and/or interactional effects do not appear in such a model. The test score variables are determined by two variables only: (a) by the latent *trait* and (b) by the corresponding error variable ε_{ik} (see Figure 2).

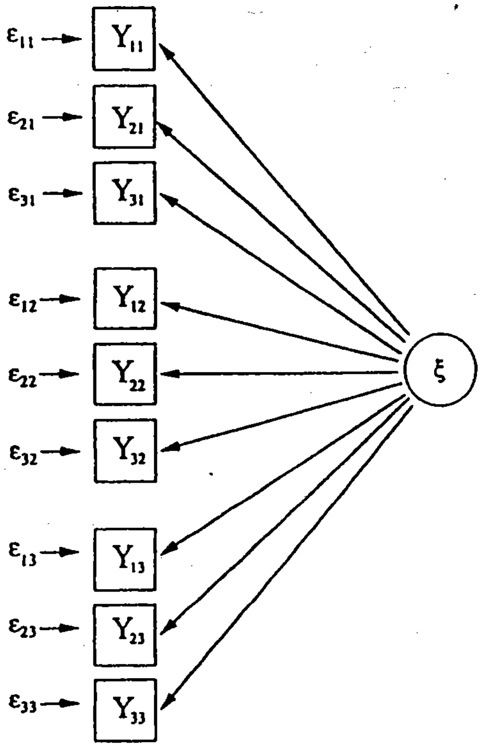

Figure 2. A latent trait model for three manifest variables Y_{ik} on each of three occasions, the occasion being indicated by k. For simplicity, in this and the next four figures all effects are set equal to 1. In general, these effects might differ from each other. See Table 2 for the relation between ξ and the latent state variables τ_{ik}. The latter are not depicted in this and the remaining figures.

As will be shown in the application section, neglecting the problem of occasion specificity may lead to a rejection of the model even in an application in which traits are *intended* to be measured such as in Spielberger's trait anxiety inventory.

Latent State (LS) Models

In order to take into account occasion specificity *and* measurement error, *latent state models* or *multistate models* may be used. We present two classes of latent state models. In the first class all Y variables pertaining to occasion k measure the same latent state η_k (occasion-specific congenerity) and all ε variables are uncorrelated among each other (uncorrelated errors).

Table 3. Assumptions and Some Consequences of the Latent State Model Without Method Factors

Assumptions

(a) $Y_{ik} = \tau_{ik} + \varepsilon_{ik}$ — Occasion-Specific Congenerity

$= \alpha_{ik} + \lambda_{ik}\,\eta_k + \varepsilon_{ik}$,

where $E(\varepsilon_{ik} \mid p_0, p_k) = 0$ and $\alpha_{ik}, \lambda_{ik} \in \mathbb{R}$,

(b) $Cov(\varepsilon_{ik}, \varepsilon_{jl}) = 0, \quad (i,k) \neq (j,l)$, — Uncorrelated Errors

Some Consequences of the Assumptions

(1) $Cov(\tau_{ik}, \tau_{jl}) = \lambda_{ik}\,\lambda_{jl}\,Cov(\eta_k, \eta_l)$ — Covariances and

(2) $Var(\tau_{ik}) = \lambda_{ik}^2\,Var(\eta_k)$ — Variances of Latent States

(3) $Var(\varepsilon_{ik}) = Var(Y_{ik}) - \lambda_{ik}^2\,Var(\eta_k)$ — Variances of Measurement Errors

(4) $Rel(Y_{ik}) = \dfrac{\lambda_{ik}^2\,Var(\eta_k)}{Var(Y_{ik})}$ — Reliability

Note: See note to Table 2.

Table 3 displays these assumptions and those consequences which relate the basic concepts of General LST Theory to the concepts of the specific LS model defined by the assumptions. This type of tables is useful for practical purposes, too, because the formulas displayed show how to estimate the parameters of General LST Theory, once the estimates of the parameters of the specific LS model are obtained (e.g., estimated by a program for the analysis of simultaneous equation models).

Again, each test score variable is determined by two variables only: (a) by the *latent state* and (b) by the error variable (see Figure 3). However, in contrast to the class of latent trait models presented above, there is one latent state variable for each occasion.

The models presented above require that all variables Y_{ik} within each occasion k of measurement measure exactly the same construct. In many cases, however, it will be difficult to construct two or more different measurement instruments that fulfill this requirement. A more realistic assumption is that although the different instruments (e.g., test forms) measure a common factor, they also measure a factor that is specific for each instrument. Take, for instance, the measurement of extraversion on an occasion k of measurement by self ratings, Y_{1k}, and by peer ratings, Y_{2k}. It seems reasonable to assume that both variables will measure the common factor *extraversion*. However, they may also be affected by the method-specific factors pertaining to the methods of self rating and peer rating, respectively. Some

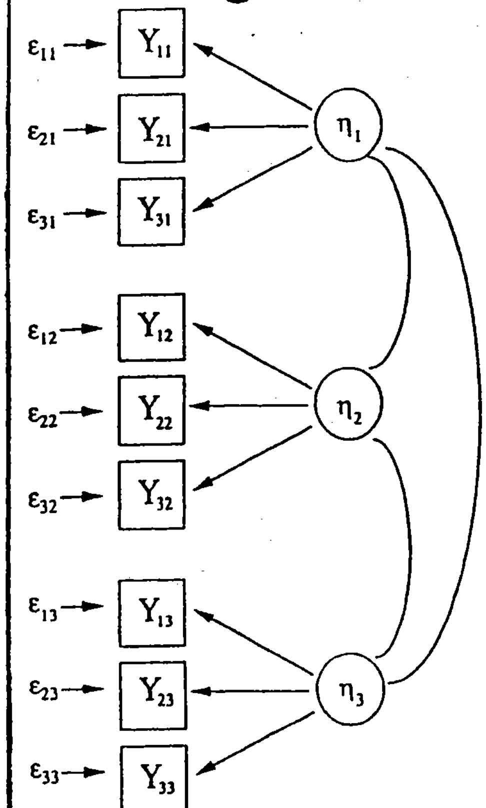

Figure 3. A latent state model for three manifest variables on each of three occasions. See Table 3 for the relation between the η_k and the latent state variables τ_{ik}.

subjects may overestimate their extraversion while their peers may underestimate it, and for other subjects it might be the other way round. Hence, if the same methods are applied on *all* occasions of measurement and if we assume that the biases of the methods are stable, we may specify models including a specific factor for each different method. In the sequel we will use the term *method factors* no matter whether these factors are due to different methods of measurement (such as self rating vs. peer rating) or only to different instruments of the same kind (such as different test forms).

In the second class of LS models, the multistate-multimethod models (see Table 4), we allow for factors which are specific for the measurement instruments. Each latent state variable τ_{ik} is a linear combination of a component η_k that is *common* for the occasion and a component ξ_i that is *specific* for

Table 4. Assumptions and Some Consequences of the Latent State Model With Method Factors.

Assumptions

(a) $Y_{ik} = \tau_{ik} + \varepsilon_{ik}$ — Weak Congenerity

$= \alpha_{ik} + \lambda_{ik}\,\eta_k + \xi_i + \varepsilon_{ik}$,

where $E(\varepsilon_{ik} \mid p_0, p_k) = 0$ and $\alpha_{ik}, \lambda_{ik} \in \mathbb{R}$,

Noncorrelation between:

(b) $Cov(\varepsilon_{ik}, \varepsilon_{jl}) = 0, \quad (i,k) \neq (j,l)$. — Measurement Errors

(c) $Cov(\varepsilon_{ik}, \eta_l) = 0$ — Measurement Errors & Latent States

(d) $Cov(\xi_i, \xi_j) = 0, \quad i \neq j$, — Method Factors

(e) $Cov(\xi_i, \varepsilon_{jl}) = Cov(\xi_i, \eta_k) = 0$ — Method Factors & Others

Some Consequences of the Assumptions

(1) $Cov(\tau_{ik}, \tau_{jl}) = \lambda_{ik}\,\lambda_{jl}\,Cov(\eta_k, \eta_l), \quad i \neq j, k \neq l$ — Covariances of Latent States

(2) $Cov(\tau_{ik}, \tau_{jk}) = \lambda_{ik}\,\lambda_{jk}\,Var(\eta_k), \quad i \neq j$

(3) $Cov(\tau_{ik}, \tau_{il}) = \lambda_{ik}\,\lambda_{il}\,Cov(\eta_k, \eta_l) + Var(\xi_i), \quad k \neq l$

(4) $Var(\tau_{ik}) = \lambda_{ik}^2\,Var(\eta_k) + Var(\xi_i)$ — Variances of Latent States

(5) $Var(\varepsilon_{ik}) = Var(Y_{ik}) - [\lambda_{ik}^2\,Var(\eta_k) + Var(\xi_i)]$ — Variances of Measurement Errors

(6) $Rel(Y_{ik}) = \dfrac{\lambda_{ik}^2\,Var(\eta_k) + Var(\xi_i)}{Var(Y_{ik})}$ — Reliability

$= cRel(Y_{ik}) + mSpe(Y_{ik})$,

where $cRel(Y_{ik}) = \dfrac{\lambda_{ik}^2\,Var(\eta_k)}{Var(Y_{ik})}$ — Common Reliability

and $mSpe(Y_{ik}) = \dfrac{Var(\xi_i)}{Var(Y_{ik})}$ — Method Specificity

Note: See note to Table 2.

the variables Y_{ik} with the same first index. Note that the loadings of the Y variables on the method factors ξ_i could change between occasions, in principle. However, for simplicity of presentation, we assume loadings equal 1 on the method factors throughout this paper.

The first component η_k of the Y variables might be called the "common latent state variable" and the second component ξ_i the "method factor" or the "specific latent trait". The latter name makes sense because each measurement instrument (indexed i) may have a *specific* component that is not shared with the other measurement instruments but remains the same across all occasions. The component ξ_i is called a (specific) latent *trait*, because its values do not change across occasions. Hence, they characterize the properties of *persons* with respect to the specific measurement instrument i.

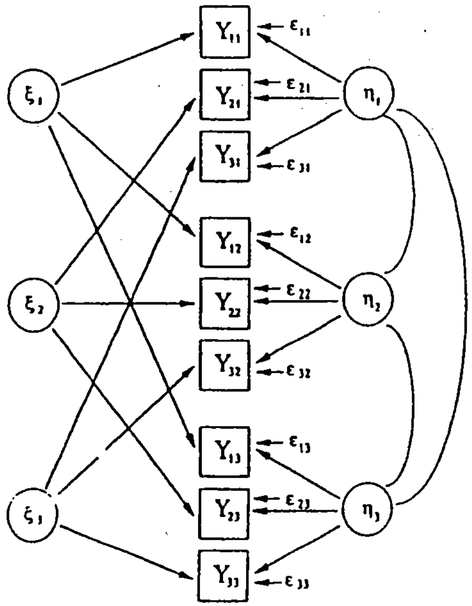

Figure 4. A latent state model with method factors for three manifest variables on each of three occasions. See Table 4 for the relation of the latent state variables τ_{ik} to the η_k and ξ_i.

In both classes of models, the latent state variables pertaining to different occasions of measurement may differ from each other. They might be correlated or uncorrelated. Hence, both types of models may be used to investigate the stability of the latent state variables. The relevant formulas are displayed in Tables 3 and 4.

Note the distinction between the variables τ_{ik} and η_k! Whereas the variables η_k occurring in the simultaneous equation models (see Figures 3 and 4) are only of technical interest, the variables τ_{ik} are the latent state variables defined in General LST Theory. It is their variance that yield the reliability coefficients if divided by the variance of the corresponding variable Y_{ik}.

Latent State-Trait (LST) Models

The latent state models discussed above have some disadvantages which stem from the fact that no *common* latent trait is defined. Hence, within such a model it is not possible to formulate the relations between states and traits. Therefore, these models do not allow for a decomposition of the variances of the latent state variables into a trait component and a residual component representing the effects of situations and interactions between persons and situations.

State *and* trait variance components can be separated only within a latent state-trait model. Two classes of these models are defined by the set of assumptions displayed in Tables 5 and 6, respectively. Although models with trait variables that change across occasions are compatible with General LST Theory, both classes of models presented here assume a *single* common latent trait variable. Hence, they may also be called singletrait-multistate models and singletrait-multistate-multimethod models, respectively.

Latent state models and latent state-trait models differ in the additional introduction of a common factor ξ accounting for the covariances of the factors η_k (see Figure 5). In the first class of models (see Table 5) all Y variables pertaining to occasion k measure the same latent state η_k (occasion-specific congenerity of the Y variables), all latent state variables η_k measure the same latent trait ξ (congenerity of the variables), all ζ variables are uncorrelated among each other (uncorrelated ζ variables), all ε variables are uncorrelated among each other (uncorrelated ε variables), and all ε variables are uncorrelated with all ζ variables. Further restrictions on the covariances (see Equations 27 to 29) between these variables already follow from the Equations 13 to 17 defining the latent variables and residuals.

In the second class of models we allow for method factors which are specific for each measurement instrument. Just as in the latent state model, each latent state variable τ_{ik} is a linear combination of a factor η_k common for the occasion k and a method factor ξ_i specific for the variables with index i.

In contrast to the class of models presented in Figure 5, $\xi_{ik} = E(Y_{ik} \mid p_0)$ is *not* a linear function of the latent variable ξ. Instead, ξ_{ik} is a linear combination of a trait component that is common for all occasions of measurement and another trait component ξ_i that is specific for the measurement instrument i. Again, the relations between latent state and trait variables as defined in General LST Theory and the latent variables appearing in the model of Figure 6 are displayed in Table 6.

Both classes of latent state-trait models allow for the distinction between measurement errors *and* situational/interactional effects, because aside from the latent *state* and *trait* variables, they incorporate the residuals representing situational and/or interactional effects for each occasion of measurement (see Figures 5 and 6).

Table 5. Assumptions and Some Consequences of the Latent State-Trait Model Without Method Factors.

Assumptions	
(a) $Y_{ik} = \tau_{ik} + \varepsilon_{ik} = \alpha_{ik} + \lambda_{ik}\eta_k + \varepsilon_{ik}$, where $E(\varepsilon_{ik} \mid p_0, p_k) = 0$ and $\alpha_{ik}, \lambda_{ik} \in \mathbb{R}$,	Occasion Specific Congenerity
(b) $\eta_k = \beta_k + \gamma_k \xi + \zeta_k$, where $E(\zeta_k \mid p_0) = 0$ and $\beta_k, \gamma_k \in \mathbb{R}$,	Congenerity of η's
	Noncorrelation between:
(c) $Cov(\varepsilon_{ik}, \varepsilon_{jl}) = 0$, $(i,k) \neq (j,l)$,	Measurement Errors
(d) $Cov(\varepsilon_{ik}, \eta_l) = 0$	Measurement Errors & Latent States
(e) $Cov(\zeta_k, \zeta_l) = 0$, $k \neq l$	Latent State Residuals
(f) $Cov(\zeta_k, \varepsilon_{il}) = Cov(\zeta_k, \xi) = 0$	Latent State Residuals & Others
Some Consequences of the Assumptions	
(1) $Cov(\tau_{ik}, \tau_{jl}) = \lambda_{ik}\lambda_{jl}\gamma_k\gamma_l Var(\xi)$, $i \neq j, k \neq l$	Covariances of Latent States
(2) $Cov(\tau_{ik}, \tau_{jk}) = \lambda_{ik}\lambda_{jk}\gamma_k^2 Var(\xi) + \lambda_{ik}\lambda_{jk} Var(\zeta_k)$, $i \neq j$	
(3) $Cov(\tau_{ik}, \tau_{il}) = \lambda_{ik}\lambda_{il}\gamma_k\gamma_l Var(\xi)$, $k \neq l$	
(4) $Var(\tau_{ik}) = \lambda_{ik}^2\gamma_k^2 Var(\xi) + \lambda_{ik}^2 Var(\zeta_k)$	Variances of Latent States
(5) $Cov(\xi_{ik}, \xi_{jl}) = \lambda_{ik}\lambda_{jl}\gamma_k\gamma_l Var(\xi)$, $i \neq j$	Covariances of Latent Traits
(6) $Cov(\xi_{ik}, \xi_{il}) = \lambda_{ik}\lambda_{il}\gamma_k\gamma_l Var(\xi)$	
(7) $Var(\xi_{ik}) = \lambda_{ik}^2\gamma_k^2 Var(\xi)$	Variances of Latent Traits
(8) $Var(\zeta_{ik}) = \lambda_{ik}^2 Var(\zeta_k)$	Variances of Latent State Residuals
(9) $Var(\varepsilon_{ik}) = Var(Y_{ik}) - [\lambda_{ik}^2\gamma_k^2 Var(\xi) + \lambda_{ik}^2 Var(\zeta_k)]$	Variances of Measurement Errors
(10) $Rel(Y_{ik}) = \dfrac{\lambda_{ik}^2\gamma_k^2 Var(\xi) + \lambda_{ik}^2 Var(\zeta_k)}{Var(Y_{ik})}$	Reliability
(11) $Con(Y_{ik}) = \dfrac{\lambda_{ik}^2\gamma_k^2 Var(\xi)}{Var(Y_{ik})}$	Consistency
(12) $Spe(Y_{ik}) = \dfrac{\lambda_{ik}^2 Var(\zeta_k)}{Var(Y_{ik})}$	Occasion Specificity

Note: See note to Table 2.

The latent state-trait models involve a more liberal concept of a latent trait than the latent trait model depicted in Figure 2, because they allow for situational and/or interactional effects. In this type of model, the value of a manifest variable depends on the measurement errors and on a latent state variable, which itself is determined by the latent trait and by situational and/or interactional effects. This holds true for both classes of latent state-trait models, although the relations between the latent variables occurring in the simultaneous equation models on one hand and the latent state and trait variables on the other hand is more complicated in the models with method factors.

The following two extreme cases illustrate the range of empirical situations that may be conceived within the two classes of latent state-trait models:

(1) The manifest variables Y_{ik} depend only on measurement error and the common trait. In this case, the latent state-trait model simplifies to the latent trait model shown in Figure 2, because the variances of the variables ξ_k and of the method factors ξ_i are zero. This would be the ideal case from the perspective of the classical trait approach to the assessment and study of personality, aptitude, and attitudes.

(2) The manifest variables depend only on measurement error and on the latent state. The latent state itself does not depend on the traits. This coincides with the model depicted in Figure 3 with the additional restriction of uncorrelated latent state variables η_k. The variance of the common trait variable ξ is zero, each variable η_k is identical with ζ_k, and the variances of the method factors ξ_i are zero.

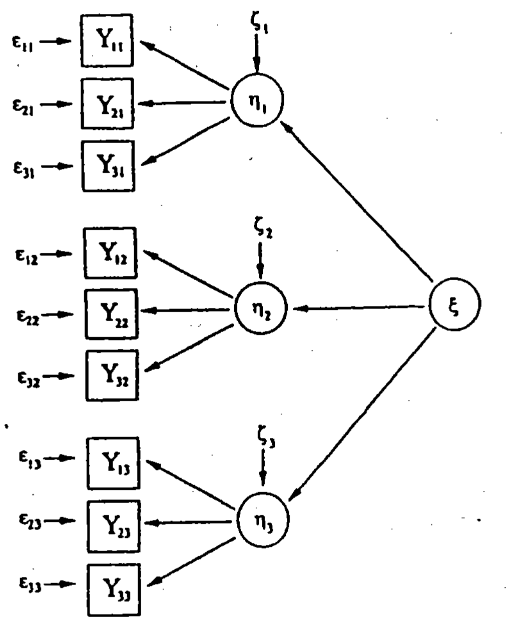

Figure 5. A latent state-trait model for three manifest variables on each of the three occasions. See Table 5 for the relation between the η_k and the latent state variables τ_{ik}.

This would be the ideal case from the perspective of the pure situationist who denies the existence of stable behavioral dispositions. For an example of this extreme case see Nesselroade, Pruchno, and Jacobs (1986).

Within the latent state-trait models depicted in Figures 5 and 6, we may identify consistency, occasion specificity, and reliability as proportions of variance of the manifest variables which are determined by the latent variables occurring in the models (see Tables 5 and 6).

Furthermore, the latent state-trait models with method factors (see Figure 6) allow for a decomposition of the consistency coefficient into two additive proportions, the *common consistency* and the *method specificity* coefficients (Table 6).

In the latent trait models and in the latent state-trait models discussed above, there is only one single latent trait for all occasions of measurement considered. General LST Theory, however, allows for several latent traits that change across occasions as well. If, for instance, there are two phases of measurement with a relatively long interval between them and each phase may be characterized by Figure 5 or 6, then we would have two different latent

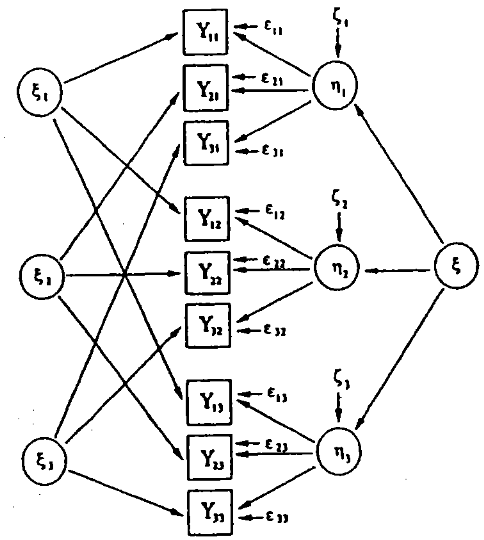

Figure 6. A latent state-trait model with method factors for three manifest variables on each of the three occasions. See Table 6 for the relation of the latent state variables τ_{ik} to the η_k and ξ_i.

traits. The correlation of these traits might be the object of interest.

Applications

In order to illustrate the models outlined above, we will now present data from studies on anxiety and coping. The data from these studies were analyzed via LISREL 7 (Jöreskog & Sörbom, 1989) to estimate the parameters and test hypotheses.

Anxiety

The data of our first application were taken from research on anxiety, a field in which most studies on the state-trait distinction have been conducted. The German version of Spielberger's State-Trait Anxiety Inventory (STAI; Laux, Glanzmann, Schaffner, & Spielberger, 1981) was given to several groups of about 30 volunteer university students at the end of a lecture on two different occasions about 8 weeks apart. A total of 179 first and second year students from the University of Trier participated in both waves of this study. The numbers of females (n =

Table 6. Assumptions and Some Consequences of the Latent State-Trait Model With Method Factors.

Assumptions

(a) $Y_{ik} = \tau_{ik} + \varepsilon_{ik} = \alpha_{ik} + \lambda_{ik}\eta_k + \xi_i + \varepsilon_{ik}$, where $E(\varepsilon_{ik}|p_0,p_k) = 0$ and $\alpha_{ik}, \lambda_{ik} \in \mathbb{R}$ — Weak Occasion Specific Congenerity

(b) $\eta_k = \beta_k + \gamma_k\xi + \zeta_k$, where $E(\zeta_k|p_0) = 0$ and $\beta_k, \gamma_k \in \mathbb{R}$ — Congenerity of η's

Noncorrelation between:

(c) $Cov(\varepsilon_{ik}, \varepsilon_{jl}) = 0, \ (i,k) \neq (j,l)$ — Measurement Errors

(d) $Cov(\varepsilon_{ik}, \eta_k) = 0$ — Measurement Errors & Latent States

(e) $Cov(\zeta_k, \zeta_l) = 0, \ k \neq l$ — Latent State Residuals

(f) $Cov(\zeta_k, \varepsilon_{il}) = Cov(\zeta_k, \xi) = 0$ — Latent State Residuals & Others

(g) $Cov(\xi_i, \xi_j) = 0, \ i \neq j$ — Method Factors

(h) $Cov(\xi_i, \varepsilon_{jl}) = Cov(\xi_i, \eta_k) = Cov(\xi_i, \zeta_k) = 0$ — Method Factors & Others

Some Consequences of the Assumptions

(1) $Cov(\tau_{ik}, \tau_{jl}) = \lambda_{ik}\lambda_{jl}\gamma_k\gamma_l Var(\xi), \ i \neq j, k \neq l$ — Covariances of Latent States

(2) $Cov(\tau_{ik}, \tau_{jk}) = \lambda_{ik}\lambda_{jk}\gamma_k^2 Var(\xi) + \lambda_{ik}\lambda_{jk} Var(\zeta_k), \ i \neq j$

(3) $Cov(\tau_{ik}, \tau_{il}) = \lambda_{ik}\lambda_{il}\gamma_k\gamma_l Var(\xi) + Var(\xi_i), \ k \neq l$

(4) $Var(\tau_{ik}) = \lambda_{ik}^2\gamma_k^2 Var(\xi) + \lambda_{ik}^2 Var(\zeta_k) + Var(\xi_i)$ — Variances of Latent States

(5) $Cov(\xi_{ik}, \xi_{jl}) = \lambda_{ik}\lambda_{jl}\gamma_k\gamma_l Var(\xi), \ i \neq j$ — Covariances of Latent Traits

(6) $Cov(\xi_{ik}, \xi_{il}) = \lambda_{ik}\lambda_{il}\gamma_k\gamma_l Var(\xi) + Var(\xi_i)$

(7) $Var(\xi_{ik}) = \lambda_{ik}^2\gamma_k^2 Var(\xi) + Var(\xi_i)$ — Variances of Latent Traits

(8) $Var(\zeta_{ik}) = \lambda_{ik}^2 Var(\zeta_k)$ — Variances of Latent State Residuals

(9) $Var(\varepsilon_{ik}) = Var(Y_{ik}) - [\lambda_{ik}^2\gamma_k^2 Var(\xi) + \lambda_{ik}^2 Var(\zeta_k) + Var(\xi_i)]$ — Variances of Measurement Errors

(10) $$Rel(Y_{ik}) = \frac{\lambda_{ik}^2\gamma_k^2 Var(\xi) + \lambda_{ik}^2 Var(\zeta_k) + Var(\xi_i)}{Var(Y_{ik})} = cRel(Y_{ik}) + mSpe(Y_{ik}),$$ — Reliability

where $cRel(Y_{ik}) = \frac{\lambda_{ik}^2\gamma_k^2 Var(\xi) + \lambda_{ik}^2 Var(\zeta_k)}{Var(Y_{ik})}$ (Common Reliability) and $mSpe(Y_{ik}) = \frac{Var(\xi_i)}{Var(Y_{ik})}$ (Method Specificity)

(11) $$Con(Y_{ik}) = \frac{\lambda_{ik}^2\gamma_k^2 Var(\xi) + Var(\xi_i)}{Var(Y_{ik})} = cCon(Y_{ik}) + mSpe(Y_{ik}),$$ — Consistency

where $cCon(Y_{ik}) = \frac{\lambda_{ik}^2\gamma_k^2 Var(\xi)}{Var(Y_{ik})}$ (Common Consistency)

(12) $$Spe(Y_{ik}) = \frac{\lambda_{ik}^2 Var(\zeta_k)}{Var(Y_{ik})}$$ — Occasion Specificity

Note: See note to Table 2.

90) and males (n = 89) were approximately equal. Two parallel forms were constructed for both scales of the STAI (see Steyer, Schwenkmezger, & Auer, 1990). In addition to substantive aspects, item statistics such as means and standard deviations were taken into account for the construction of parallel forms. The covariance matrix of all test halves and both occasions of measurement are displayed in Table 7.

Latent Trait (LT) Models

First, the covariance matrix (see Table 7) was analyzed separately for the state anxiety and trait anxiety scales according to the LT model presented in Table 2. This model had a bad fit (χ^2_8 = 265.03) for *the state* anxiety scales. Because *states* on two different occasions should have a less than perfect correlation, this result was expected. The modification indices suggest that in fact there is a high correlation

Table 7. Sample Variances and Covariances for the State and Trait Anxiety Test Halves

	SA_{11}	SA_{12}	SA_{21}	SA_{22}	TA_{11}	TA_{12}	TA_{21}	TA_{22}
SA_{11}	24.67							
SA_{12}	21.90	25.14						
SA_{21}	10.35	10.62	27.24					
SA_{22}	11.67	12.64	25.26	28.68				
TA_{11}	13.30	14.87	7.23	9.04	22.54			
TA_{12}	12.73	14.85	7.36	8.95	18.74	21.45		
TA_{21}	11.84	12.67	11.39	11.89	15.49	15.36	20.98	
TA_{22}	11.24	11.37	9.83	10.78	14.85	16.24	17.80	20.45

Note: SA_{ik} denotes state anxiety, *i*th test half, *k*th occasion, and TA_{ik} trait anxiety, *i*th test half, *k*th occasion.

between the residuals *within* each of the two occasions of measurement. (The corresponding two modification indices are 142.9.)

What might be surprising is that similar results are obtained for the *trait anxiety* test halves. Although the model fit ($\chi^2_8 = 80.77$) is considerably better than for the state test halves, it is far from being acceptable. Again, the modification indices suggest that there is a high correlation between the residuals *within* each of the two occasions of measurement (the corresponding modification indices are 76.4). The bad model fit and the pattern of modification indices suggest that there might be situational and/or interactional effects which are common for those trait test halves that were assessed within the same occasion of measurement.

Latent State (LS) Models

One possibility to take into account common sources of variance of the variables *within* each of the occasions is to specify an LS model. Since the test halves were constructed as "parallel" forms, the loadings were fixed to one. Furthermore, since the parallel forms were given on two occasions, *same* parallel forms were given on two occasions, the error variances were constrained to be equal within and between occasions. The results of the analysis of the *state* anxiety test halves based on this model are presented in Figure 7. The variances and covariances implied by this model are well in accord with their empirical counterparts ($\chi^2_8 = 7.53$; $p = .27$). The latent state variables correlate .48.

For the *trait* anxiety test halves, the fit of the latent state model is only moderate ($\chi^2_8 = 17.80$; $p = .01$). We analyzed this model according to the LS model with method factors. The results of this analysis are depicted in Figure 8. Compared to the latent state test halves, the two latent state variables correlate much higher ($r = .83$).

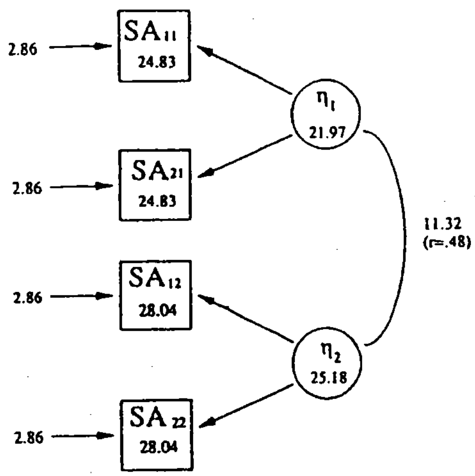

Figure 7. Latent state model for two state anxiety test halves on two occasions. The numbers displayed are the variances of the corresponding variables except for the covariance of the variables η_1 and η_2. Model fit: $\chi^2_8 = 7.53$ ($p = .27$); adj. goodness of fit = .97; root mean square residual = .67.

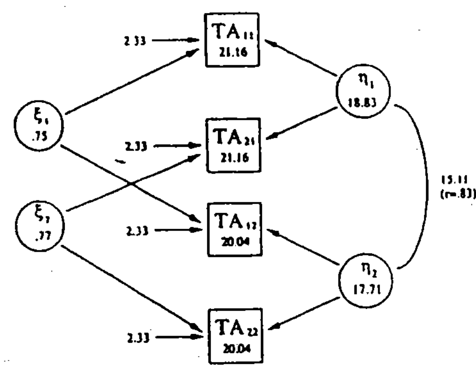

Figure 8. Latent state model with specific traits for two trait anxiety test halves on two occasions. The numbers displayed are the variances of the corresponding variables except for the covariance of the variables η_1 and η_2. Model fit: $\chi^2_4 = 6.74$ ($p = .15$); adj. goodness of fit = .95; root mean square residual = .35.

The fit of this model is acceptable ($\chi^2_4 = 6.74$; $p = .15$). Figure 8 shows that the variances of the method factors are small (.75 and .77, respectively). Nevertheless, they are significant even at the .01-level as the difference between the χ^2 values for the models without and with method factors, respectively, indicate: $\chi^2_8 - \chi^2_4 = 17.80 - 6.74 = 11.04$). This means that

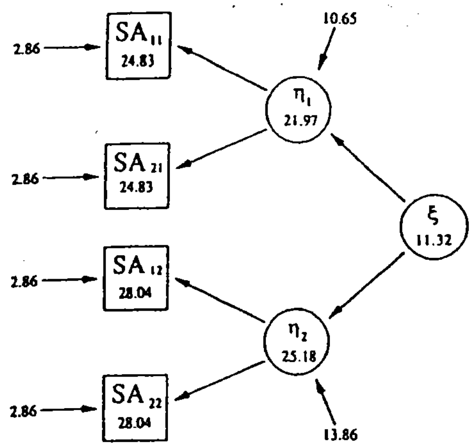

Figure 9. Latent state-trait model for two state anxiety test halves on two occasions. The numbers displayed are the variances of the corresponding variables. Same model fit as in Figure 7.

the test halves are not strictly parallel. In addition to their *common* trait components, each test half also has a *method* factor indicating that the meanings of the items are not identical in the two test halves.

Latent State-Trait (LST) Models

Although the LS models presented in Figures 7 and 8 are acceptable with respect to their model fit, there are theoretical reasons that suggest to prefer LST models: the possibility to decompose the variance of the latent state variables into the variance determined by a *common* trait and a residual variance due to situational and/or interactional effects. Hence, we again analyzed the data, this time according to the LST model. The results of this analysis for the state anxiety test halves are summarized in Figure 9.

The fit statistics are the same as in the LS model. In fact, in this special case with $n = 2$ occasions, the LS models and the LST models imply the same covariance matrix. Hence, only the theoretical reasons mentioned above suggest to prefer the LST model.

The same kinds of models were analyzed for the *trait* anxiety test halves yielding the same goodness of fit statistics as the corresponding LS models. Since the model without method factors does not fit, we choose to depict only the model with method factors (see Figure 10). Whereas in the LS model it is only possible to compute the reliability coefficients,

Table 8. Consistency, Specificity, and Reliability of the Test Halves of the State and Trait Anxiety Scales

	State Anxiety Scales		Trait Anxiety Scales			
Occasion	1	2	1		2	
Test Half	1, 2	1, 2	1	2	1	2
Consistency	.46	.40	.72	.72	.76	.76
common	.46	.40	.70	.69	.73	.73
specific	.00	.00	.02	.03	.03	.03
Specificity	.43	.49	.17	.17	.13	.13
Reliability	.89	.90	.89	.89	.89	.89

Note: The LST model with specific traits for trait anxiety implies unequal variances of the test halves within each occasion. Therefore, the coefficients of the test halves slightly differ from each other.

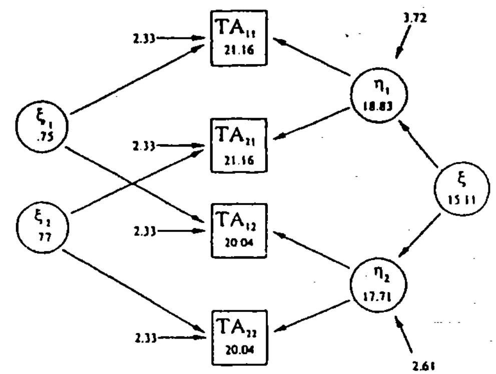

Figure 10. Latent state-trait model with method factors for two trait anxiety test halves on two occasions. The numbers displayed are the variances of the corresponding variables. Same model fit as in Figure 8.

we are now able to compute the consistency and occasion specificity coefficients and to split the consistency coefficient into the common consistency and the method specificity (see Table 8).

Note that the computation of the coefficients for state anxiety are based on the covariance matrix implied by the model depicted in Figure 9. The formulas displayed in Table 5 simplify in this application because all coefficients λ_{ik} and γ_k are equal to one. The computation of the coefficients for trait anxiety are based on the covariance matrix implied by the model depicted in Figure 10.

Discussion

As can be seen from Table 8, the coefficients of consistency reveal that the scores on the state anxiety test halves are determined to a considerable degree by the latent *trait*, although the intention is to measure *states*. The coefficients also show, however, that the instructions of the state and trait inventories *do* have an effect, because the consistency coefficients of the *trait* anxiety test halves are much larger than those of the *state* variables. The occasion specificity coefficients indicate, however, that some variance of the trait anxiety scales is due to situations and/or interactions as well. This confirms our general argument that situations and/or interactions usually have an effect on psychological measures even if they are constructed with the *intention* to measure traits.

A special problem of this application is that the covariance matrices implied by the LS models and the LST models are the same. Hence, the assumption of a single latent trait explaining the covariance of the latent states cannot be tested. However, the only reason is that there are only two occasions of measurement in this case. Our next example illustrates how such a test may be accomplished if there are more than two occasions.

Coping

Research on coping with stress in general and on coping with diseases in particular has evidenced that various psychological ways of coping exist and that individuals differ in their preferences for coping strategies (for an overview see, e.g., Lazarus & Folkman, 1984; Moos & Schaefer, 1984). The degree to which such differences are due to enduring interindividual differences and/or to situational demand characteristics is largely unclear. Some authors have conceptualized coping as a traitlike style or disposition (e.g., represser vs. sensitizer, Bell & Byrne, 1978; monitors vs. blunters, Miller & Mangan, 1983) assuming high behavioral consistencies over time as well as across stressful situations. Other theorists have conceptualized coping as classes of behavior that vary across time and types of stressors to which individuals are exposed (e.g., Lazarus & Launier, 1978).

In line with these assumptions, dispositional and episodic instruments have been developed to assess coping behavior (Cohen, 1987). Episodic instruments are focussed on temporal and situational variations of coping, whereas dispositional instruments are intended to assess those aspects of coping which are largely invariant across different situations and occasions of measurement.

Given the results for the state-trait anxiety scales reported above as well as the results from various other applications (e.g., Kirschbaum, Steyer, Eid, Patalla, Schwenkmezger, & Hellhammer, 1990; Schmitt & Steyer, in press; Steyer & Schmitt, 1990b), it seems likely that both kinds of coping measures will reflect, although to different degrees, stable individual differences *and* situational/interactional effects. The degree to which the variation of *any* coping measure is due to stable individual coping dispositions (traits) and occasion specific factors is a matter of empirical investigation. As an example, we will now present the results of various latent state-trait analyses for a specific kind of coping behavior, *search for affiliation*.

The data to be analyzed stem from a longitudinal study on coping with cancer (Filipp, Aymanns, & Klauer, 1983). Aside from medical and other psychological measurement instruments, a coping questionnaire was administered to 202 cancer patients on four occasions of measurement within one year. Five different coping strategies were assessed, one of them being "search for affiliation" (AF; for details see Klauer, Filipp, & Ferring 1989; Filipp, Klauer, Ferring, & Freudenberg, 1989). This scale describes sociable coping behavior but also diversion and attentional distraction. It consists of nine items (e.g.: "I went out with friends", "I visited or invited other people.") to be answered on six point rating scales ranging from 1 (never) to 6 (very often). From these nine items, two parallel test halves of four items each were constructed. These test halves are approximately equal with respect to average item means and standard deviations. The variances and covariances of the eight coping variables (two test halves × four occasions of measurement) are presented in Table 9.

Table 9. Sample Variances and Covariances of the Search for Affiliation Test Halves

	AF_{11}	AF_{21}	AF_{12}	AF_{22}	AF_{13}	AF_{23}	AF_{14}	AF_{24}
AF_{11}	.662							
AF_{21}	.477	.695						
AF_{12}	.425	.350	.669					
AF_{22}	.343	.449	.473	.630				
AF_{13}	.402	.311	.448	.379	.537			
AF_{23}	.344	.367	.343	.398	.358	.508		
AF_{14}	.382	.263	.431	.333	.400	.288	.615	
AF_{24}	.338	.371	.333	.387	.300	.358	.421	.580

Note: AF_{ik} denotes search for affiliation, *i*th test half, *k*th occasion.

Several LT, LS, and LST models were analyzed. The models varied in three regards: (a) whether or not the factor loadings were restricted to be equal, (b) whether or not the variances of the error variables were restricted to be equal, and (c) whether or not method factors for the two test halves were specified.

Latent Trait (LT) Models

Even the most liberal LT model (free loadings, free variances of the error variables) clearly had to be rejected (χ^2_{20} = 250; p < .01). Hence, the scores on the search for affiliation (AF) coping scale can *not* be explained by a single trait that is stable across the four occasions of measurement.

Latent State (LS) Models

To investigate whether the bad fit of the LT model is due to ignoring situational and/or interactional effects, various LS models (with fixed or free loadings, equal or unequal error variances) were specified and tested. Although these models fitted better than the LT models, they still cannot account for the covariance matrix of the eight coping measures. The model fit improves dramatically, however, if a method factor for each of the two test halves is specified. Similar to the anxiety measures discussed above, the two coping test halves are not strictly parallel.

Latent State-Trait (LST) Models

Finally, we investigated to what extent the covariances of the latent states can be accounted for by a common latent trait. Various LST models with method factors were analyzed. The model with equal error variances, unequal variances of the method factors, and unequal effects of the common latent trait on the four latent states was accepted (χ^2_{25} = 37.57; p > .05). The parameters of this model are given in Figure 11.

Based on the model shown in Figure 11 and the formulas given in Table 6, the coefficients of reliability, consistency, and occasion specificity were computed for the eight coping variables (cf. Table 10).

Discussion

The results of our analyses demonstrate that search for affiliation is neither exclusively a trait-like coping style nor is it determined by situational demands, only. However, the proportions of variances explained by stable individual differences are much higher than those accounted for by situational and/or interactional effects. Thus, *search for affiliation* as a coping behavior of cancer patients seems to be trait-like primarily.

The method factors for the test halves indicate that the two test halves do not measure exactly the same coping behavior. Instead, each test half has a specific component that cannot be ignored if an adequate explanation of the covariance matrix is intended. The two tests are not parallel test forms in the sense that they may be used interchangeably. Each one comprises of coping behaviors which are specific to some degree. Therefore, they are indicative of the same common latent state and the common latent trait only in part.

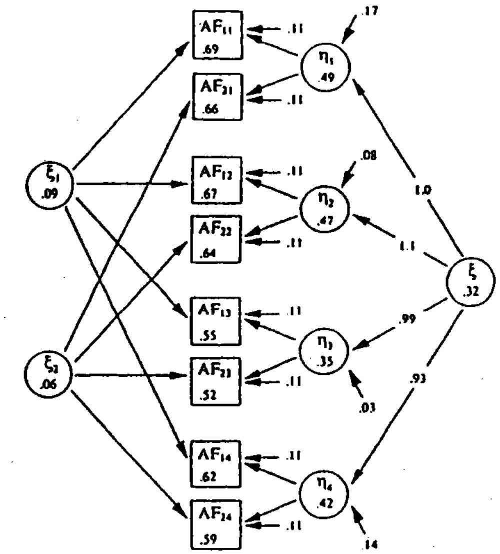

Figure 11. Latent state-trait model with method factors for two search for affiliation test halves on four occasions. Model fit: χ^2_{22} = 28.22 (p = .17); adj. goodness of fit = .95; root mean square residual = .05.

Table 10. Consistency, Specificity, and Reliability of the Search for Affiliation Test Halves

Occasion	1		2		3		4	
Test Half	1	2	1	2	1	2	1	2
Consistency	.60	.58	.73	.60	.75	.74	.60	.66
common	.47	.49	.59	.51	.58	.63	.46	.56
specific	.13	.09	.14	.09	.17	.12	.15	.10
Specificity	.25	.26	.12	.12	.06	.06	.22	.24
Reliability	.85	.84	.84	.72	.81	.80	.82	.90

General Discussion

The distinction between states and traits has been a matter of controversial debates (see e.g., Allen &

Potkay, 1981, 1983; Zuckerman, 1983). It is closely related to the person-situation debate revolving around the question to which extent behavior is determined by stable dispositions versus characteristics of the situation (for a review see Schmitt, 1990). We consider our approach useful not only for the state-trait distinction but also, more generally, for correlational research addressing the relative weight of traits and situations for explaining and predicting behavior. With regard to this issue, our approach supplements traditional ANOVA designs in that *naturally occurring* situations are considered which may differ between individuals at the occasion of measurement.

The goal of our contribution has been to present a coherent theory relating observable variables (e.g., obtained by psychological assessment procedures) to the state and trait constructs. We started out with a critical discussion of traditional approaches to the state-trait distinction: (a) the *operational approach* (e.g., Spielberger, 1972, 1983) and (b) the *autocorrelation approach* (e.g., Hertzog & Nesselroade, 1987). Conceptually, both approaches are appealing. However, when it comes to relate theory and empirical data, they are not convincing.

We have criticized Spielberger's operational approach to the state-trait distinction via different instructions in questionnaires (Spielberger, 1972, 1983) arguing that *psychological assessment never takes place in a situational vacuum* and that situations may have an effect on subjects' answers even to those questionnaires that are developed for the assessment of traits. This argument has been supported by the results of our analyses for the state-trait anxiety data: the LT model had to be rejected for the *trait* anxiety test halves.

According to our view, Hertzog and Nesselroade's distinction between states and traits on the basis of the size of their autocorrelations is arbitrary to some extent. Furthermore, this approach does not take into account "that most psychological attributes will neither be, strictly speaking, traits or states. That is, attributes can have both trait and state components" (Hertzog & Nesselroade, 1987, p. 95). The critical point is that these state *and* trait components do not appear in their structural equation models.

Our approach can be seen as a generalization of Classical Test Theory which considers *persons-in-situations* as units of measurement. In this conceptual framework definitions of states and traits as well as of reliability, consistency, occasion specificity, and stability have been proposed. We have defined a *latent state* as any measurement that is free from measurement error and a *latent trait* as any measurement that is free from measurement error *and* free from situational and interactional effects. Furthermore, we have supplemented the classical concept of reliability by two coefficients: the *consistency coefficient*, which is the proportion of variance of an observed variable due to interindividual differences (which are not due to situational and/or interactional effects), and the *occasion specificity coefficient*, which is the proportion of variance due to (a) the different situations that may occur for different persons on an occasion of measurement, and (b) the person-situation interaction. The sum of both coefficients is the reliability coefficient for the occasion of measurement considered. Within this approach, the situationists' as well as the trait psychologists' goals are accounted for since latent state-trait theory considers both sources of variance and allows for a quantitative estimation of additive variance components.

Five classes of models were presented that supplement the general theory outlined above. The assumptions defining these models imply special confirmatory factor models. Hence, parameter estimation and hypothesis testing may be accomplished by computer programs for the analysis of structural equations such as LISREL (Jöreskog & Sörbom, 1989), EQS (Bentler, 1989), or LISCOMP (Muthén, 1988).

Traits as defined in this paper are *not* unchangeable and genetically determined. The concept of a latent trait allows for systematic fluctuations at each occasion of measurement not being due to measurement error, but to situational variability. If there are only *two* occasions, the assumption of a latent trait ξ is tautological, i.e., it is not empirically testable. However, for $n \geq 3$ occasions, the assumption of a latent trait restricts the covariances of the latent state variables to be equal, if the coefficients γ_k (see Figures 5 or 6) are all equal to one. For $n \geq 4$ occasions, the assumption of a latent trait restricts the covariances of the latent state variables even if the coefficients γ_k are all different from each other. The hypothesis that a single latent trait explains the covariation of the latent states is empirically testable by standard simultaneous equation methods.

The proposed concept of a latent trait already allows for the existence of latent *states*. If the manifest variables are intended to measure traits, these states may be called "biased traits". They are necessary for taking into account situational and/or interactional variability (see Figure 10). The restriction imposed by the assumption of a latent trait is that the trait should explain the covariances of the latent states.

Our state-trait distinction is similar to that of Hertzog and Nesselroade (1987) and to conceptualizations of traits by Epstein (1979, 1980; Epstein & O'Brien, 1985) and Zuckerman (1983). However, in our models, states and traits do not hover as hidden constructs over the models of data analysis but are integral parts of these models. The variances, covariances, and correlations of the latent states and traits among each other as well as with other variables can be directly estimated and tested.

In general, psychological tests and other observations do not measure *only* states or *only* traits as has been suggested by Allen and Potkay (1981). Instead, each test may be decomposed into a latent state and an error variable, and the latent states may be decomposed into a latent trait and a latent state residual (see Table 2). Hence, latent states and latent traits are not incompatible with each other. Instead, a latent trait is one of the components constituting the latent state. However, the *proportion* of variance of the latent state that is determined by the latent trait may range from zero to one; its size may be estimated in empirical applications via simultaneous equation modeling. For this purpose we need repeated measurements on at least two occasions with at least two instruments measuring the same states. The situations in which measurement takes place do not have to be known and do not have to be observed. The natural variation of situations between occasions and the natural differences between subjects (persons-in-situations) within each occasion of measurement is sufficient.

A general consequence of our approach is that it makes possible to focus psychological theory on explaining *both* states and traits. Obviously, situational characteristics (such as recent threat experiences, recent social support, etc.) have to be considered as explanatory variables if latent *states* are focussed, whereas genetic, learning, and socialization factors may explain individual differences in traits. More complex latent state-trait models involving these kinds of explanatory variables seem to be most interesting for future research.

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Errors

found in Steyer, Ferring, Schmitt (1992). States and Traits in Psychological Assessment. European Journal of Psychological Assessment, Vol. 8, pp. 79-98.

In figure 8 and in figure 10 the variances of the manifest variables must be: $Var(TA_{11})=21.91$; $Var(TA_{21})=21.93$; $Var(TA_{12})=20.79$; $Var(TA_{22})=20.81$.

Table 8. Consistency, Specificity, and Reliability of the Test Halves of the State and Trait Anxiety Scales

	State Anxiety Scales		Trait Anxiety Scales			
Occasion	1	2	1		2	
Test Half	1, 2	1, 2	1	2	1	2
Consistency	.46	.40	.72	.72	.76	.76
common	.46	.40	.69	.69	.73	.73
specific	.00	.00	.03	.03	.04	.04
Specificity	.43	.49	.17	.17	.13	.13
Reliability	.89	.90	.89	.89	.89	.89

Table 10. Consistency, Specificity, and Reliability of the Search for Affiliation Test Halves

Occasion	1		2		3		4	
Test Half	1	2	1	2	1	2	1	2
Consistency	.60	.58	.73	.71	.75	.73	.60	.58
common	.47	.49	.59	.62	.58	.62	.46	.48
specific	.13	.09	.13	.09	.16	.11	.15	.10
Specificity	.25	.26	.11	.12	.06	.06	.22	.24
Reliability	.85	.84	.84	.83	.81	.80	.83	.82