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# Latent state–trait theory: An application in sport psychology

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ABSTRACT

*Objective:* Questionnaires are often applied in sports psychology to measure a person's trait or state. However, the extent to which the questionnaire captures differences because of trait or state influences is often unclear. The latent state–trait (LST) theory offers the opportunity to separate both variance sources. This separation allows estimating specific reliability coefficients.

*Design:* The present paper gives a theoretical introduction to LST and its basic ideas. Using a real data set with $N = 156$ athletes we exemplify the steps necessary to derive the LST coefficients. All athletes filled out a comprehensive inventory assessing competitive anxiety on two occasions.

*Method:* The data are analysed with structural equation models based on LST principles.

*Results:* The results confirm the questionnaire's trait saturation.

*Conclusion:* Finally, results are discussed in light of practical and theoretical implications.



Psychologists use tests and questionnaires to measure individual differences. Such individual differences are often perceived as relatively stable across time and situations and are called traits. Traits can be seen as parts of personality (Maltby, Day, & Macaskill, 2007, p. 605). The idea is that based on these measurements, predictions regarding future behavior or performance can be made. Yet, sometimes it is more interesting to measure states that reflect temporary conditions that are not stable across situations and time. Moreover, empirical results have not always confirmed a strong relationship between measured traits and actual behavior in specific situations. This observation sparked the person–situation debate, which has been going on for quite a while now (Bowers, 1973; Epstein, 1997; Epstein & Obrien, 1985). Deinzer et al. (1995) concluded: "… we always measure persons in situations, not persons; there is no psychological measurement in the situational vacuum (p. 7)." This statement, along with the need to measure states in certain settings, highlights the importance of situational circumstances in the measurement of individual differences. This important role of situational circumstances is especially relevant in sports psychology. For example, when measuring competitive anxiety, it makes a difference whether an athlete is close to an important competition or still a long time away from it. That means sports psychologists should know how big the proportions of state and trait variance are in their assessment tools. For example, if we wanted to select young athletes for a national team based on certain psychological characteristics, we would want to assess individual differences that are consistent across situations and times, and that are not due to a specific situation. That means the state proportion should be low. Yet, when treating problems associated with choking under pressure, states might be of greater interest and consequently, the state proportion should be higher.

Nowadays, it is possible to quantify the amount of variance due to a trait, the situation or state, their interaction as well as measurement error. Steyer and colleagues introduced the latent state–trait (LST) theory that provides the theoretical background and statistical techniques needed (Steyer, Ferring, & Schmitt, 1992; Steyer, Schmitt, & Eid, 1999). The present paper aimed at introducing the basics of LST theory and provides a practical example for conducting the analyses. The example used data obtained with a questionnaire measuring competitive anxiety.

## Latent state–trait theory: an introduction

The basic mathematical problem was how to separate an item's variance into variance due to trait, situation (or state), interaction between person and situation, and measurement error. Defining a situation and its properties is a difficult task. Measuring specific

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situation attributes seems even more challenging. LST theory provides one possible solution to the problem. Using structural equation modeling, LST theory provides a framework in which it is possible to distinguish between the different variance sources without defining or measuring situational aspects. In LST, specific coefficients can be computed containing information on consistency, occasion specificity, and reliability of an instrument in a given sample and situation. In the following paragraphs, we outline the basic ideas and concepts before providing a practical example.

*Basic idea*

LST theory was based on the idea that a person's score in any given test is at least partially determined by situational circumstances. As mentioned above, it makes a difference whether an athlete is actually in the middle of a competition or still a few weeks before one. Let us assume we wanted to measure an athlete's competitive anxiety, i.e., concerns he or she generally has regarding potential failure in a competition. To measure this trait, we use four items with a 4-point rating scale with higher ratings indicating higher anxiety. If we asked the athlete six weeks before the year's most important competition, he or she might still be quite relaxed and involved in training. The scores on the four items might be 1, 2, 2, and 1. However, if we asked the same four questions on the day of the competition, the athlete may currently be anxious and the scores might then be 2, 2, 3, and 4. Based on classical test theory, we would assume that the scores at both times were a compound of the athlete's true score (true concerns as a trait) and measurement error. The basic formula for this is $X_{pi} = T_{pi} + E_{pi}$. The score $X$ of a person $p$ in a test $i$ is a combination of the person's true score, $T_{pi}$, and measurement error, $E_{pi}$. LST theory extended this idea. It assumed that the scores are results of random experiments. The athlete was drawn from a population of athletes and the measurement times were drawn from a population of $t$ possible situations. Obviously, the scores changed between the measurement times because of the changed situation. The athlete's trait could not be responsible for this change. Neither should the measurement error be able to fully explain the change. However, the specific situational circumstances influencing the athlete's state can be used as an explanation. It was therefore necessary to extend the basic formula and add a situation-specific index $t$: $X_{pit} = T_{pit} + E_{pit}$. The true score variable $T_{pit}$ is called *latent state variable* in LST theory. However, this is just a technical term and does not indicate that actually a state is measured. Rather than that, it should be understood as a latent trait biased with situation and the interaction between situation and person (Deinzer et al., 1995, p. 5). This definition indicates that the latent state variable $T_{pit}$ can be understood as a combination of individual differences in the *latent trait* $\xi_{pit}$ ($X_i$) and variance due to the situation and the situation by person interaction. The latter two variance sources cannot be separated and are called the *latent state residual* $\zeta_{pit}$ (Zeta). This is the amount of variance in the latent state variable that is not explained by differences in the latent trait. Hence, it must contain systematic differences due to the situation (state) and the situation by person interaction. Trait variance reflects differences between individuals due to their different trait values. Situation variance on the other hand reflects the systematic effect that the specific situation in which a person was assessed had on the measurement. Finally, the situation by person interaction captures in how far people reacted differently to the same situation. All measurement error influences are comprised in the error term $E_{pit}$. The basic formula for a test score in LST reads: $X_{pit} = \xi_{pit} + \zeta_{pit} + E_{pit}$. Based on this reasoning, it is possible to separate the different variance sources. Fig. 1 illustrates the decomposition of variance. The observed variable $X_{it}$ can be divided into latent state variance $T_{it}$ and error variance $E_{it}$. The latent state variance can then be separated into latent trait $\xi_{it}$ and latent state residual $\zeta_{it}$ variance, respectively.

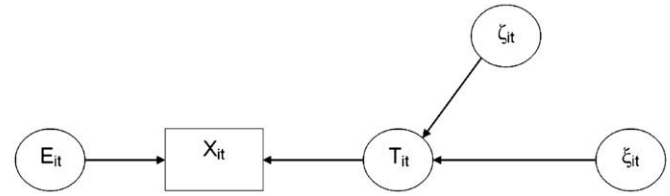


**Fig. 1.** Variance decomposition. $E_{it}$ = measurement error variance of item $i$ at time $t$; $X_{it}$ = observed score for item $i$ at time $t$; $T_{it}$ = latent state variable $i$ at time $t$; $\zeta_{it}$ = latent state residual; $\xi_{it}$ = latent trait.

Based on this variance decomposition, the LST coefficients reliability (REL), consistency (CON), and occasion specificity (SPE) can be computed. The equations are:

$$\mathrm{REL}(X_{it}) = \frac{\mathrm{Var}(T_{it})}{\mathrm{Var}(X_{it})} = \frac{\mathrm{Var}(\xi_{it}) + \mathrm{Var}(\zeta_{it})}{\mathrm{Var}(X_{it})}$$

$$\mathrm{CON}(X_{it}) = \frac{\mathrm{Var}(\xi_{it})}{\mathrm{Var}(X_{it})}$$

$$\mathrm{SPE}(X_{it}) = \frac{\mathrm{Var}(\zeta_{it})}{\mathrm{Var}(X_{it})}$$

Reliability has often been operationalized as the amount of true score variance present in the total observed variance (Novick, 1966). In this sense, true score variance only includes systematic differences between persons. All unsystematic differences are defined as error. Thus, the reliability (REL) of the test score is the amount of observed total variance explained by latent trait and latent state residual variance. The total variance represents the observed variance. Systematic true score differences can be found in the latent trait variable as well as the latent state residual. These variance sources contain all the systematic variance, either due to trait, situation or the situation by person interaction.

The consistency (CON) of the score equals the amount of total observed variance explained by the latent trait. In other words, the consistency quantifies the amount of trait specific variance and thus, variance that is present independent of situational circumstances. The larger the consistency is, the higher the trait impact.

Occasion specificity (SPE) represents the amount of total observed variance due to the latent state residual and, hence, due to the situation and the situation by person interaction. Thus, occasion specificity shows how much a measurement instrument captures situation-specific variance in a given sample and situation, so that finally it can be derived from these considerations, that the reliability is the sum of consistency and specificity.

However, with just one single time of measurement, it would not be possible to split the latent state variance. The problem is solved by using at least two times of measurement. Now it is possible to define a *Multi-State-Single-Trait model*. In this model, it is assumed that one and the same trait was measured in more than one situation. In our example, we measured the athlete's competitive anxiety twice with a gap of four days in between. The model looks like the one depicted in Fig. 2.

As can be seen from the model, the four items $X_1$ to $X_4$ were asked at two measurement points, as indicated by the second index. Because the same trait was measured at both times, the latent state variables only need an index indicating the measurement point. The same holds true for the latent state residuals. The latent trait variable in this model explains systematic differences in the latent state variables at each time, caused by individual trait differences. Consequently, it explains trait variance, which is inherent in both situations. The latent state residuals in this model contain variance that cannot be explained by the trait acting at both