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The personality triad in balance: Multidimensional individual differences in situation–behavior profiles☆

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Abstract

A new methodology is proposed to study the full personality triad including persons, situations, and responses. It is based on a model of the structural mechanism underlying behavioral data in terms of eliciting power of situations, response thresholds, as well as quantitative and/or qualitative individual differences. The model is aimed at conceptually clarifying the personality triad and makes it possible to derive individual differences in situation–behavior profiles (or behavioral signatures) starting from empirically gathered person-by-situation-by-response data. It is particularly well-suited to capture multidimensional individual differences—implying complex person by situation and/or person by response interactions—and to examine the psychological mechanisms underlying them. In an application to anger-in and anger-out in interpersonal frustrating situations, three person types were derived that were characterized in terms of distinctive behavioral signatures. Part of the differences in behavioral signatures could be explained in terms of hostile encoding and hostile expectancy processes.
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Keywords: Personality triad; Situation–behavior profiles; Multidimensionality

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Introduction

Problem description

The study of personality properly encompasses three elements: persons, situations, and behaviors. All of these three elements are equally important since empirical research has demonstrated that not every person responds in the same way to each situation, and, furthermore, that there may be complex interactions between persons, situations, and behaviors in the determination of behavior (Funder, 2001; Mischel & Shoda, 1995, 1998; King & Endler, 1990). However, in his recent *Annual Review* paper, Funder (2001) convincingly remarked that the accumulated research literature with respect to this personality triad is unbalanced because two out of the three of its elements—situations and behaviors—have received only a small amount of attention in theory and empirically research (for exceptions however, see Cervone, 1997; Endler, Parker, Bagby, & Cox, 1991; Mischel & Shoda, 1995, 1998; Van Heck, Perugini, Caprara, & Fröger, 1994; Van Mechelen & Kiers, 1999).

In this paper, we want to propose a methodology that takes the full personality triad into account, linking up with more comprehensive approaches in personality research, including the triple typology approach (Bem, 1983; Vansteelandt & Van Mechelen, 1998), Mischel and Shoda's Cognitive–Affective Personality System theory (1995, 1998), social-cognitive theories on personality (for an overview, see Cervone & Shoda, 1999), and extended trait theories amended with concepts like trait-relevance of situations and behaviors (Johnson, 1997). The methodology makes it possible to study individual differences in behavior in relation to the context (or the situation) in which the behaviors occur; specifically, it allows the researcher to derive situation–behavior profiles, and substantial individual differences in such profiles, starting from empirically gathered person-by-situation-by-behavior data.

Mischel and Shoda (1995, 1998) call such distinctive situation–behavior profiles the behavioral signature of the persons, which reflects their personality. Provided aggregation over a sufficient number of measurement occasions, such behavioral signatures have been shown to be fairly stable over time (Mischel & Shoda, 1995). Conceiving personality in terms of behavioral signatures implies that the probability for a particular person to display a particular behavior in a particular situation is seen as a function of certain features of the person, the situation, and the behavioral act involved. Within this context, important questions include: What are relevant person, situation, and behavior features? How are these features related to the probability of a person displaying a behavior in a situation? and, especially, how can all this be investigated? With regard to the latter, it may be noted, that, although the theoretical importance of individual differences in situation–behavior profiles has been repeatedly and convincingly demonstrated (e.g., Mischel & Shoda, 1995, 1998), strategies and tools to identify relevant person, situation, and behavior features and their interrelations are still largely lacking. To fully understand personality, it is further of utmost importance to understand the psychological mechanisms underlying such situation–behavior profiles. In this conceptual approach, context, behavior, psychological processes are inseparable and essential components in the

study of personality (Cervone & Shoda, 1999; Mischel & Shoda, 1995; Zelli & Dodge, 1999).

The methodology we will propose in the present paper provides a tool to deal with the questions as outlined above. By proposing it, we hope to contribute to a further conceptual clarification of the personality triad from a comprehensive approach to the study of personality (Bem, 1983; Cervone & Shoda, 1999; Johnson, 1997; Mischel & Shoda, 1995). In addition, we wish to provide the personality researcher with tools to derive individual differences in situation–behavior profiles in a behavioral domain of interest, and to understand its process basis; as such, we want to make the personality triad amenable to empirical research.

Major features of the proposed methodology

Before describing the methodology more in detail, we now want to highlight two major features of it. First, the to be proposed methodology allows one to model quantitative and/or qualitative individual differences in situation–behavior profiles. When individual differences in situation–behavior profiles are purely quantitative in nature, the personality triad can be represented in terms of a uni-dimensional model in that the probability of a person displaying a response in a situation can be modeled in terms of the positions of persons, situations, and responses on, respectively, one person, one situation, and one response dimension (Vansteelandt, 1999). However, an abundant amount of research indicates that such uni-dimensionality is rather the exception than the rule in the personality domain (Endler et al., 1991; Higgins, 1990; Ozer & Reise, 1994; Van Heck et al., 1994; Van Mechelen & Kiers, 1999). To take this into account, we start from the assumption that the population of persons may be heterogeneous with respect to situation–behavior profiles; as such, it is assumed in the new model that there may exist a number of subpopulations (of persons), for each of which a distinct submodel applies. *Within* each subpopulation, persons can still differ on a specific dimension for that subpopulation, resulting in quantitative individual differences in situation–behavior profiles; the latter means that the situation–behavior profiles of the different persons belonging to the subpopulation can differ from one another in level but not in shape. *Between* subpopulations, there may further be quantitative or qualitative individual differences; the latter means that the average situation–behavior profiles of the subpopulations may differ in level or shape. As such, the model allows for dimensional variation within subpopulations or types. Note that with the proposed methodology, the answer to the question whether different subpopulations (or person types) exist (and, if yes, how many of them) does not have to be known in advance for the behavioral domain of interest and may be derived from the empirical data. As such, the proposed methodology can be considered an instance of model-based cluster analysis (the model being a mixture of subpopulation-specific logistic regression models). A further major advantage of the to be proposed approach is that it allows one to model complex person by situation and/or person by response interactions in a parsimonious way.

Second, the methodology is based on a model of the structural mechanism underlying behavioral data in terms of eliciting power of situations, response thresholds, as

well as (both quantitative and qualitative) individual differences. Moreover, this mechanism can be further given a substantive interpretation by relating it to potentially relevant underlying psychological processes. As such, the methodology is process-oriented and may provide an answer to calls that processes should play a more prominent role in personality research (Diener, 1996). With regard to the aspect of process orientation, the to be proposed methodology can be distinguished from the Triple Typology Model (TTM) we proposed previously to study individual differences in situation–behavior profiles (Vansteelandt & Van Mechelen, 1998). In the TTM, persons, situations, and responses are classified in (hierarchically organized) person, situation, and response types, respectively; each person type is further characterized by a set of if (situation type) then (response type) rules that indicate which response types are displayed by which person types in which situation types. All in all, the TTM is a purely descriptive model that summarizes how certain types of persons display certain types of responses in certain types of situations; unlike the to be proposed model, it does not elucidate how the three types of entities jointly result in the coming about of (individual differences in) behavior.

The organization of the rest of this paper is as follows. In the personality triad: the probability of persons displaying behaviors in situations, the questions mentioned above concerning relevant person, situation and behavior features and how these are related to the probability of a person displaying a behavior in a situation are elaborated more in detail. In a methodology to capture multidimensional individual differences in situation–behavior profiles, we propose our new methodology. Whereas this methodology is generally applicable to all behavioral domains, in Illustrative application, we will illustrate it with an empirical study on individual differences in anger in various frustrating interpersonal situations. In general discussion, some remarks are made on the distinction between categories and dimensions and on the issue of model selection. We finish this section by situating the model within the family of logistic regression models; in this context, some advantages of the proposed model are discussed.

The personality triad: the probability of persons displaying behaviors in situations

Within a contextualized approach to personality, differences in the probability of persons displaying particular behaviors in particular situations are conceived as a function of features of the person, the situation and the behavior. In this section, we will first successively discuss each of these three types of features. Next, we will discuss how the three types of features may jointly relate to the probability of behavior. Throughout we will use the case of anger and anger-related behavior as a guiding example.

With respect to the *persons*, the most obvious person features to think of are dispositional constructs like, for example, trait anger. Persons may take a different position on a trait dimension and the higher their position on the trait dimension, the higher the probability that they will display trait–relevant behavior. However, also more process-related constructs may be considered (see for example Zelli & Dodge,

1999). For example, with respect to anger, one could think of hostile encoding (Dodge, 1993); the latter concept refers to the tendency of a person to interpret interpersonal, aversive situations as purposefully aggressive—irrespective of the actual intent of the other person to whom they interact (Dodge, 1993). Persons may take a different position on a hostile encoding dimension, with persons with a stronger hostile encoding tendency having a larger probability to display angry behavior in interpersonal aversive situations. For example, in Fig. 1, the level of anger-related behavior of three persons in three situations is displayed. In this respect, we may assume that Person A and C have high and low positions, respectively, on the anger-trait or hostile encoding dimension. Other possibly relevant process-variables may include individual differences in the expectancy of negative consequences of displaying anger (Rubin, 1986) with persons who expect more negative consequences taking a lower probability of displaying anger-related behavior in interpersonal, negative situations.

Situations may be characterized in terms of active psychological features (Mischel & Shoda, 1995, 1998), that is, features of a situation that render a meaning to it and that have an impact on the behavior in it (e.g., the presence or absence of another person in the situation; whether the other person in the situation has an equal or a higher status, and so forth). Situations may take a different position on dimensions related to such active psychological features, for example, a frustration-induction dimension. In this case, one may assume that the higher the position of the situation on the frustration-induction dimension, the larger the probability that a person will display angry behavior in it. In Fig. 1, the order of the situations corresponds to the number of minutes that another person is late for an appointment, which may reflect differences in the amount of frustration that is induced—the active psychological feature involved.

Finally, *behaviors* may be characterized in terms of response features; such features may relate to the ease with which a behavior is displayed, that is, their response

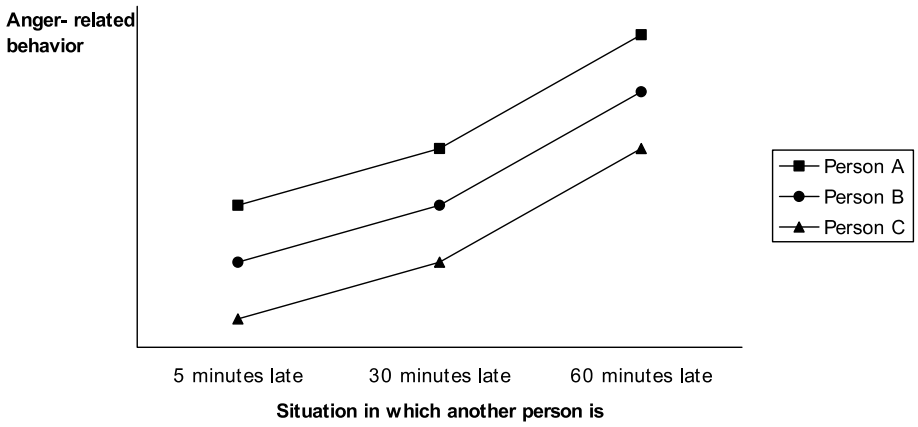


Fig. 1. Hypothetical situation–behavior profiles of three persons who differ in hostile encoding tendency.

threshold (Vansteelandt, 1999). Then, the response thresholds correspond to the positions of the responses on a response dimension. For example, physically angry behaviors may have higher response thresholds than verbally angry behaviors because they imply a higher risk of causing physical damage to the other person. In Fig. 2, one can see, for example, that all persons have a higher probability of saying nasty things than actually hitting someone else in a situation in which someone is 60 min late reflecting the different response thresholds of both responses.

Given person, situation, and response features, one may wonder how they jointly relate to response probability. In this respect, one of the most simple mechanisms may be that the persons, situations, and responses are, respectively, located on a person feature, a situation feature and a response feature dimension and that, subsequently, person, situation, and response contributions simply additively combine into response probability. When this is the case, the probability that a particular person will display a particular response in a particular situation will be large (small) when (a) the person has a high (low) position on the person feature dimension, (b) when the situation takes a high (low) position on the frustration-induction dimension, and (c) when the response has a low (high) response threshold. For example, Person A will have a high probability to say nasty things when someone is 60 min late for an appointment because (a) this person has a high position on a hostile encoding dimension, (b) the situation has a high position of the frustration-induction dimension, and (c) saying nasty things has a low response threshold.

It is important to note that a simple additive mechanism as outlined above implies that the positions of the situations and the responses on the single underlying dimension are the same for all persons. These assumptions may, however, be too stringent since multidimensionality is often found in personality research (Ozer & Reise, 1994). For the situations, there is, for example, ample empirical evidence that the

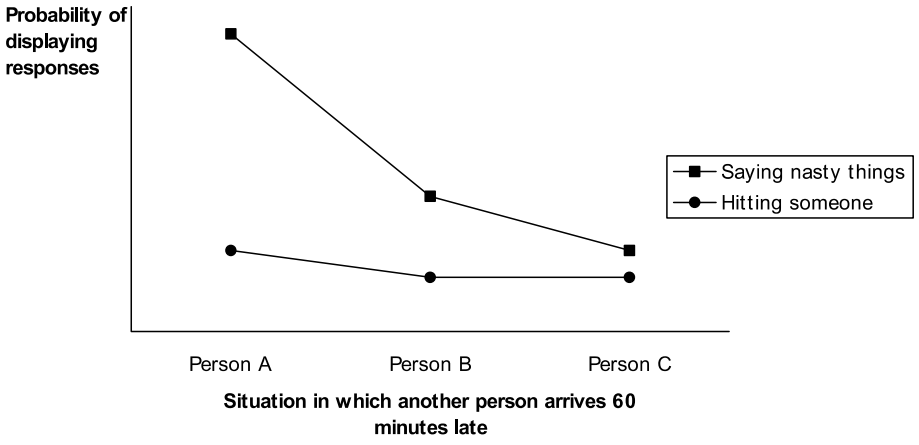


Fig. 2. Hypothetical probabilities of three persons to display two angry responses in a situation in which someone arrives 60 min late for an appointment.

positions of situations on a relevant underlying dimension may differ across persons (Endler et al., 1991; Higgins, 1990; Van Heck et al., 1994). In Fig. 3, an example of possible behavioral consequences of such a multidimensionality is given. It can be seen in this figure that, for Person D, the situation in which another person is 20 min late for an appointment elicits more anger-related behavior than the situation in which another person spills coffee, whereas for Person F, it is the other way around. Such individual differences in the positions of the situations may be due to the fact that (a), as a result of their learning history, different persons perceive the same situations differently, (b) they focus on different aspects of the situation (Bernstein, Borkovec, & Coles, 1986) or (c) they transform the same objective situations in such a way that they are experienced differently (Mischel, 1999). One possibility to understand the individual differences in Fig. 3 is to assume that Person D and Person F belong to two, qualitatively different, person types with each person type being characterized by a different relevant order of situations. In this case, it is impossible to predict in which out of two situations the probability of displaying anger-related behavior is the highest without taking the person type into account; in other words, this implies that there exist substantial interactions between persons and situations.

For the responses, also abundant empirical evidence exists that the order of the responses on relevant underlying dimensions may not be the same for all persons. In the case of anger, for example, substantial individual differences exist in the way persons express the anger they experience: Some persons typically express their anger to persons or objects in the environment (anger-out) while other persons may typically keep their anger in (anger-in). Given the empirical evidence that anger-in and anger-out are independent dimensions (Spielberger & Sydeman, 1994), the response thresholds of anger-in and anger-out responses should be different for persons who score high on anger-in and low on anger-out in comparison to persons who score the other way around. As a consequence, the order of the response thresh-

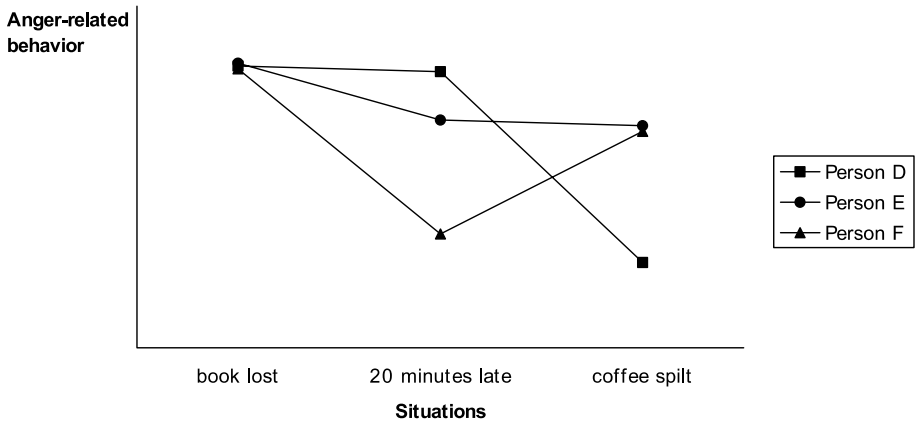


Fig. 3. Hypothetical example of three persons with different orders of situations on a relevant underlying situation dimension.

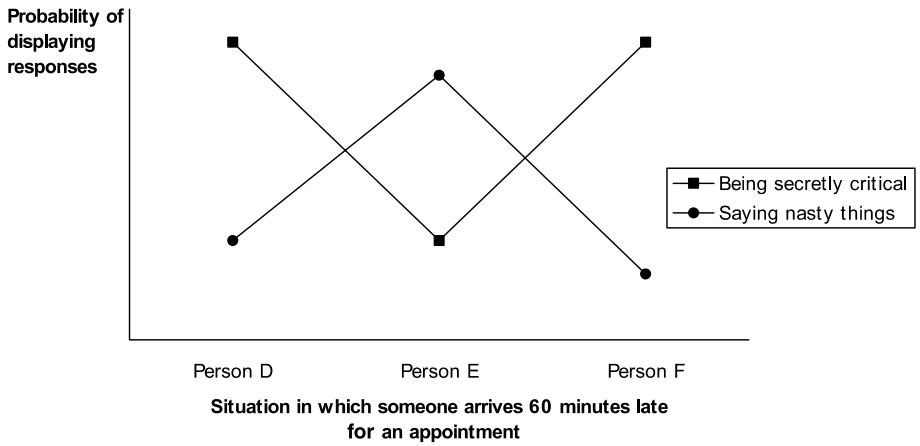


Fig. 4. Hypothetical example of three persons with different orders of responses on a relevant underlying response dimension.

olds for anger-in and anger-out responses may be different for different subpopulations of persons (or person types). In Fig. 4, as a hypothetical example, it can be seen that Person E has a high probability for saying nasty things and a low probability for being secretly critical when someone arrives 60 min late for an appointment while for Person F the opposite patterns holds. Several studies (Endler et al., 1991; Evans & Gall, 1988; Lang, 1977; Michelson, 1984; Van Heck et al., 1994) have documented the existence of such individual differences in the response system that is most sensitive in relation to the same stimulus situation. This implies that one should take the person type into account when one wants to predict which out of two responses has the highest probability of being displayed; this further implies the existence of substantial person by response interactions. The new model we will propose offers a tool to study such a multidimensionality (when the order of situations and responses in terms of response probability is different for different person types).

A methodology to capture multidimensional individual differences in situation–behavior profiles

Given an account of individual differences in situation–behavior profiles in terms of one or more underlying dimensions, it may be desirable to have a methodology available for empirical research on the basis of it. In a first stage, one may wish to estimate the positions of persons, situations, and responses on the underlying dimension(s) starting from empirical person $\times$ situation $\times$ response data. Subsequently, in a second stage, one may wish to relate these estimated positions to external structure- or process-related variables in order to understand *why* persons, situations and responses are low or high on a dimension. A feature of the methodology we propose is that it allows one to estimate in the first stage the positions of persons, situations

and responses simply and solely on the basis of the person × situation × response data. In this stage, no information on person features, situation features or response features is needed; as such, the relevant features emerge from the behavioral data. Subsequently, the psychological meaning of the induced features may be retrieved by relating the estimated person, situation, and response positions to external structure- or process-related variables. The advantage of this approach is that the first stage may give rise to new hypotheses about potentially relevant psychological mechanisms underlying individual differences in situation–behavior profiles within a behavioral domain; in the second stage, these hypotheses can then be tested. Because of the imbalance in the personality triad, researchers often do not have good a priori ideas on relevant psychological processes for a behavioral domain; in such a case, new hypotheses may be most welcome.

For the uni-dimensional case, Vansteelandt (1999) has proposed such a methodology, which he further successfully applied to data on hostile behavior in frustrating situations. In the present section, we propose a novel extension of this methodology for the multidimensional case. Whether a uni-dimensional or a multidimensional approach is necessary for a concrete dataset is an empirical matter that will be treated later on. Before proposing the multidimensional extension, however, we first briefly recapitulate Vansteelandt's approach (1999) to the uni-dimensional case.

Uni-dimensional individual differences in situation–behavior profiles

We suppose that data are available on which responses are displayed by different persons in different situations. First, the model is explained with the help of a specific example on anger; next, it will be generalized.

Fig. 5 depicts the situation–behavior profiles of three persons across three situations: A situation in which someone lost an important book, a situation in which someone is 20 min late for an appointment and a situation in which someone spills

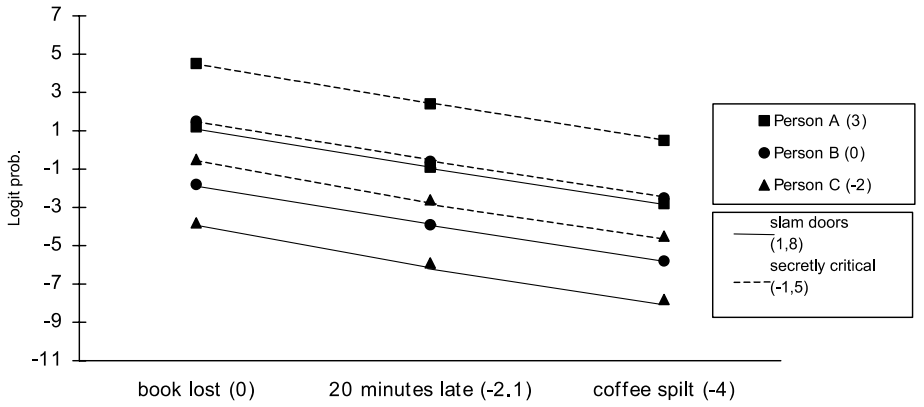


Fig. 5. Uni-dimensional individual differences in situation–behavior profiles.

coffee. In particular, this figure depicts, the (logit of the) probability that each person displays each of two behaviors (secretly critical and slam doors) in each of the three situations. It can be derived from Fig. 5 that all persons can be located on a single dimension with respect to their disposition to display anger-related behavior because for *each* situation–response combination, the order of the persons in terms of their probability to display the response in the situation is the same.[1] For example, Person A takes a higher position on this dimension than Person C, because in each situation Person A has a larger probability to display each anger response than Person C. It also turns out from Fig. 5 that all situations can be ordered on a single dimension with respect to the degree to which they elicit angry behavior; when one examines the probabilities that a given person will display a given response in each of the involved situations, it can be seen that the order of the situations (in terms of these probabilities) is the same for all person–response combinations. Also, all responses can be ordered on a single dimension with respect to how easy they are displayed in each person–situation combination. For example, slamming doors has a higher response threshold than being secretly critical of others, because for each person it holds that the probability of slamming doors in each situation is smaller than the probability of being secretly critical of others in that same situation. The positions of the persons, the situations and the responses on the underlying formal dimension are indicated in Fig. 5 by the hypothetical values between parentheses; the exact meaning of these values will be explained below.

In the model proposed by Vansteelandt (1999), the probability that a person will display an anger-related response in a situation will be high (low) if the person has a high (low) disposition to display anger-related behavior, if the situation induces such behavior to a strong (limited) extent and if the response threshold of the response is low (high). In particular, close inspection of Fig. 5 reveals that the (logit of the) probability that a person will display an anger response in a situation can be calculated by simply adding the position of the person and the position of the situation and by subtracting the response threshold (all values being displayed between parentheses). For example, the probability that Person A (3) will slam doors (1.8) when someone else is 20 min late (−2.1) is .30 [logit $p = (3 + (-2.1) - 1.8) = -.9; p = \text{logit}^{-1}(-.9) = .30$].[2] Note that the response threshold is subtracted because a high threshold implies a low probability of displaying the response.

To generalize the model, the positions of the persons, the situations and the responses on the formal dimension are denoted by θ, γ, and δ respectively; furthermore, we denote the probability that person i will display response k in situation j by $P(X_{ijk} = 1)$. The model then implies that:

$$\text{logit } P(X_{ijk} = 1) = \theta_i + \gamma_j - \delta_k. \tag{1}$$

[1] At this stage, it may not be clear how these probabilities are calculated but this will be explained in the next paragraph.

[2] logit $p = x \Rightarrow p = \text{logit}^{-1}x = \exp x/(1 + \exp x)$.

Model (1) corresponds to the Linear Logistic Test Model, an Item Response Theory (IRT) model that is well-established in psychometric literature (for an overview, see Fischer, 1995b). In fact, this model can also be conceived as a member of the family of logistic regression models that is especially well-suited to capture uni-dimensional individual differences; to be more precise, it is a multilevel logistic regression model with a random intercept for the persons and with dummy predictors for the situations and the responses (Agresti, 2002; Agresti, Booth, Hobert, & Caffo, 2000; Rijmen, Tuerlinckx, De Boeck, & Kuppens, 2003). For the interested reader more technical information on the model is available in Appendix A. It is also important to mention that algorithms and software (e.g., von Davier, 1996; Fischer, Ponocny-Seliger, Ponocny, & Parzer, 1998; Verhelst, Glas, & Verstralen, 1994) have been developed to estimate Model (1), that is, to estimate the positions θ_i, γ_j, δ_k starting from an empirically gathered person $\times$ situation $\times$ response data set. When the estimated positions of persons, situations, and responses on the dimension then are substituted in (1), one may calculate—for each person–situation–response combination—the (logit of the) probability that the person will display the response in the situation in question. To identify the psychological meaning of the underlying person, situation and response dimension, the different positions of the persons, situations, and responses (the values between parentheses in Fig. 5) can be related to external variables, as will be illustrated in the empirical study. In this way, the researcher may understand why persons, situations, and responses are low or high on the formal dimension.

Multidimensional individual differences in situation–behavior profiles

The model proposed in the previous section implies that (a) the order of the situations in terms of the amount of angry behavior they elicit is the same for all persons and (b) the order of the response thresholds of the involved responses is the same for all persons. As argued above, sometimes, these assumptions are too stringent. In Fig. 6, an example is given in which these assumptions are not satisfied. In this figure, the situation–behavior profiles of three persons are shown for the same situations and responses as in Fig. 5.

In Fig. 6, it can be seen that the probability that Person D is secretly critical in a situation in which someone is 20 min late for an appointment is higher than in a situation in which someone spills coffee on his or her clothes; for Person E, however, the opposite pattern holds. Consequently, the order of the situations in terms of the amount of anger they elicit is different for Persons D and E. This means that it is impossible to predict which situation has the highest probability of eliciting angry behavior without referring to the person, or, in other words, that there is a (disordinal) person by situation interaction. In Fig. 6, it also appears that in all situations, Person D has a higher probability of being critical than for slamming doors while the reverse holds for Person F. This means that it is impossible to judge which response has the highest probability of being displayed in a situation without referring to the involved person, or that there is a person by response interaction.

In the new model we propose, it is assumed that Persons D, E, and F stem from different subpopulations. Each different subpopulation can be considered as a

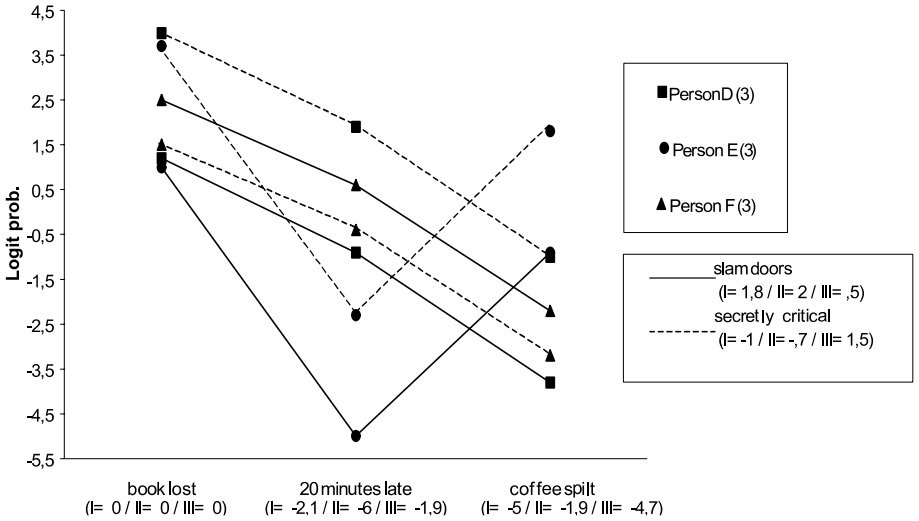


Fig. 6. Multidimensional individual differences in situation–behavior profiles (Persons D, E, F, respectively, belong to Person Types I, II, and III).

distinctive person type that is characterized by a different relevant order of the situations and the responses. The core of the new model is that for each different person type (or each different subpopulation), a different dimensional model like Model (1) holds; thus, within each discrete person type, the persons, situations, and the responses have a position on, respectively, a person, a situation, and a response dimension but these dimensions are different for the different person types. As such the hypothetical situation and response values for each person type are indicated in Fig. 6 between parentheses; in this example, there are three person types which are labeled by means of roman characters (Persons D, E, F, resp., belong to Person Type I, II, and III). Within each person type, it is further assumed that the probability that a person will display an anger response in a situation is an additive function of (a) the tendency of the person to display angry behavior, as indicated by his or her position on the person dimension of the person type, (b) the position of the situation on the anger-induction dimension for the person type under study, and (c) the response threshold of the response for the person type under study. In Fig. 6, it can be verified that the (logit of the) probability for a person to display an anger-related response in a situation is simply the sum of the positions of the person and the situation on the person type-specific dimension minus the response threshold of the person type to which the person belongs. For example, the probability that Person D, who belongs to Person Type I (3) is secretly critical (−1) in a situation in which someone is 20 min late for an appointment (−2.1) is .87 [$p = \text{logit}^{-1}(3 + (-2.1) - (-1) = \text{logit}^{-1}(1.9) = .87$] while the probability that Person E, who belongs to Person II, displays this response in this situation is .09 [$p = \text{logit}^{-1}(3 + (-6) - (-.7) = \text{logit}^{-1}(-2.3) = .09$]. Note that the values for the same situation and response are different for Person D and E because they belong to qualitatively different person types.

To generalize the new model, it is assumed that there are c different subpopulations (or c different person types); the positions of the persons, situations, and responses on the dimension for person type c are further denoted by θ_c, γ_c, and δ_c, respectively. Regarding the probability $P(X_{ijk} = 1)$ that person i will display response k in situation j, it then holds that:

$$\text{logit } P(X_{ijk} = 1) = \theta_{ic} + \gamma_{jc} - \delta_{kc}. \tag{2}$$

Note that the subscripts c indicate that the position may be different for the c different person types. Model (2) corresponds to a Discrete Mixture Distribution Linear Logistic Test Model as described in psychometric literature (Mislevy & Verhelst, 1990). This model in fact corresponds to a discrete mixture of logistic regression models (mixtures constituting the models that underlie the broad family of model-based cluster analysis methods). Leaving aside technical details, in Model (2) it is assumed that a single logistic regression model does not hold for the entire population but does so within (discrete) subpopulations of persons which are not known beforehand. In other words, for each subpopulation of persons, a distinct logistic regression model like Model (1) applies. This kind of model is especially well-suited to study individual differences while taking substantial person by situation and person by response interactions into account. For the interested reader, more technical information on Model (2) is available in Appendix B. Furthermore, it is important to note that algorithms have been developed (von Davier, 1996; Mislevy & Verhelst, 1990) and that software (von Davier, 1996) is available to estimate Model (2), that is, to induce, starting from empirical gathered person × situation × response data, a limited number of person types along with estimates of the positions $\theta_{ic}, \gamma_{jc}, \delta_{kc}$ (for each person type c). There also exist statistics (e.g., information criteria) to determine the optimal number of person types (and hence subpopulations) that are needed to represent the data. These statistical criteria yield an optimal balance between model complexity/parsimony and goodness of fit; taking too many idiosyncratic situation–behavior profiles into account would result in an overly complex model whereas taking too few distinctive situation–behavior profiles into account would result in an overly simplistic model.

Note that when only one person type is retained, Model (2) coincides with Model (1) (in this case, the model holds for the entire population). It must be emphasized that Model (2) implies individual differences both within and between person types. Persons who belong to the same person type can differ from one another because they may take different positions on the person type-specific dimension (θ_c). Persons who belong to different person types may differ from one another because, in addition, their person types are characterized by different positions of situations and response thresholds. To uncover the psychological interpretation of the person type-specific dimensions for persons, situations and responses one may further relate the θ_{ic}, γ_{jc}, and δ_{kc} estimates to external variables (e.g., hostile encoding). Furthermore, the hypothesis that persons belonging to different types will differ on external characteristics can then be tested.

Illustrative application

The goal of this application is to examine individual differences in anger when the full personality triad is taken into account. To achieve this goal, self-report data were collected making use of an experimental situation–response questionnaire with an a priori design. The choice for such a questionnaire was prompted by our awareness that the interplay between persons, situations, and responses may be very complex; an a priori design then might facilitate the interpretation of the results.

The situations in our questionnaire were constructed in such a way that they vary on a persistence of frustration dimension, a situational feature that proved to be important in previous research (Vansteelandt, 1999; Vansteelandt & Van Mechelen, 1998). In all situations, one person other than the subject was present whose status was the same as that of the subject. Status was kept constant because it was presumed that suppression of anger may relate to it (Vansteelandt, 1999). For the responses, anger-in and anger-out responses were chosen (Spielberger & Sydeman, 1994). Anger-in responses refer to feelings of anger that are experienced but held in or suppressed; anger-out responses refer to angry feelings that are expressed in aggressive behavior directed toward other people or objects in the environment. Situations and responses were fully crossed in a situation–response questionnaire.

The fact that the situations vary—on average (as judged by experts)—on one persistency of frustration dimension does not preclude that individual differences may occur with respect to the degree to which they elicit angry behavior. Such individual differences may occur due to individual differences in psychological processes like, for instance, hostile encoding (Courtney & Cohen, 1996; Dodge, 1986, 1993; Mischel, 1999) and/or hostile expectancy; the latter concept refers to the expectancy that the expression of anger in interpersonal frustrating situations will result in negative consequences for the subject. To examine the possible role of both psychological mechanisms, self-report rating scales for both individual difference variables will be used.

To retrieve the structure of individual differences in situation–behavior profiles in the expression of anger, the uni-dimensional model (1) and the multidimensional model (2) will be fitted to the data obtained with the situation–response questionnaire. This will result in a subdivision of the persons into a limited set of person types; for each person type, person membership as well as the relevant dimensional positions of the persons, the situations, and the responses will be estimated (when Model (1) fits to the data, there will be a single person type only). To interpret the situation and response dimensions of the different person types, the estimated positions of the situations will be related to expert judgments of persistency of frustration in the situation and the estimated response positions to Spielberger's classification of the responses as anger-in/anger-out. Furthermore, it will be examined to which extent hostile encoding and hostile expectancy account for individual differences both *between* and *within* person types by relating both process variables to the estimated person type membership and the positions of the persons on the person dimension of the person type to which they belong.

Method

Participants

The participants were 338 first-year psychology students at the Department of Psychology of the University of Leuven (Belgium). Participation in the study was a partial fulfillment of a requirement to participate in research. The sample consisted of 25.1% males and 74.9% females (which reflects the sex-proportion in first year psychology in Belgium). The average age was 18.5 ($SD = 1.96$, $n = 338$).

Materials

Situation–response questionnaire. A situation–response questionnaire was developed on the basis of an a priori design using two situational features: (a) persistence of the frustration in the situation (5 levels) and (b) social status of the other person present in the situation (3 levels: fellow-student, research assistant, professor). The construction of these situations was partially inspired by the S–R inventory of hostility of Endler and Hunt (1968). The persistence manipulation was validated in terms of expert judgments by ten members of the Psychology Department of the University of Leuven (Cronbach's Coefficient α for non-normalized data being .92). For the present study, we limited our analysis, for purely computational reasons, to only three situations, which correspond to three increasing levels of persistence of frustration with status kept constant (only situations with a fellow-student). The situations in question were the following ones (the mean persistence judgment on a 7-point scale averaged over experts is mentioned between parentheses after each situation): (1) As a part of an exam, you have made a paper of 15 pages and gave it to a fellow student who lost it, though. You do not have any copy of it neither on your PC nor on paper (6.60); (2) You are having an appointment with a fellow student but he (she) arrives 25 min late saying that he (she) has forgotten it (4.40); and (3) You are on the way to a seminar and a fellow student accidentally spills a small amount of coffee over your arm (2.80).

Regarding the responses, the five responses with the highest loading on the Anger-in and Anger-out scales of the Anger Expression Scale (Spielberger, Krasner, & Solomon, 1988) were taken. The selected anger-in responses are: I withdraw from people, I pout or sulk, I am angrier than I am willing to admit, I am secretly quite critical of others, and I boil inside, but I do not show it; the selected anger-out responses are: I do things like slam doors, I say nasty things, I make sarcastic remarks to others, I argue with others, and I lose my temper.

By crossing the selected three situations and the 10 responses, 30 situation–response combinations were used for the analysis.

Person characteristic questionnaire. After completing the situation–response questionnaire, subjects were asked to fill out a 12-item experimental questionnaire to assess: (1) hostile encoding (6 items; e.g., when other people get me in trouble, I rapidly think they do it on purpose) and (2) hostile expectancy (6 items; e.g., I think that, in general, the expression of anger is not appreciated by others.). Cronbach's Coefficient αs amounted to .90 and .82, respectively, indicating a satisfactory internal

consistency for both scales. Such an approach to assess process-variables proved to be fruitful in previous research (Vansteelandt & Van Mechelen, 1998).

Procedure

All situation–response combinations of the situation–response questionnaire were presented in random order. For each situation–response combination, the subjects had to indicate on a 3-point scale the extent to which he (she) would display the response in the situation in question (0 = *you do not display this response in this situation*, 1 = *you display this response in this situation to a limited extent*, 2 = *you display this response in this situation to a strong extent*). It may be noted that, thanks to the 0/not display response option, participants were not forced to indicate that they displayed any of the involved responses.

After completing the situation–response questionnaire, subjects were asked to fill out the person characteristic questionnaire. The items of this questionnaire were presented in random order. Subjects had to judge each of them with respect to the extent to which it was applicable to them on a 7-point scale (1 = *not applicable at all*, 7 = *applicable to a strong extent*).

Analysis

The 338 persons × 3 situations × 10 response data matrix was dichotomized (0 vs. 1 and 2) and analyzed using the software package called Winmira (von Davier, 1996) to estimate a Discrete Mixture Distribution Rasch Model (Rost, 1990; Rost & von Davier, 1995) resulting in c different classes of persons with different difficulty parameters for each situation–response combination in each class. To further estimate the situation and response parameters a multiple regression analysis was performed in each class of persons with the difficulties of the situation–response combinations yielded by Winmira as a criterion and dummy variables for each situation and each response as predictors.

The number of classes c is to be specified by the user; in this regard, it is common practice to estimate in a first step a series of models with increasing number of classes. The solution with one class corresponds to the uni-dimensional Model (1) whereas solutions with more classes correspond to the multidimensional Model (2). Then, in a second step, to choose the optimal number of classes, and hence, the most optimal model for the data, information criteria are used (von Davier, 1996). These criteria serve as a basis for comparing different models that are estimated for the same data; they include the numbers of parameters of each model as a penalty term, so that, given similar likelihood values, more parsimonious models are preferred (as the model with the smallest value on the information criteria has to be chosen). The use of information criteria is widespread in statistical practice on model selection because it yields an optimal balance between model complexity/parsimony and goodness of fit. In other words, in avoids overfitting the data by choosing a too complex model, but is allows for enough complexity to obtain an acceptable goodness of fit.

If a multidimensional Model (2) applies to the data, for each person, a (posteriori) probability is calculated that s(he) belongs to each of the different person types; then,

the person is assigned to the person type for which s(he) has the highest or maximum probability. (Persons who fit well in one particular person type will have a high posteriori probability for this person type and a low posteriori probability for the other person types; persons who fit neither of the person types will have similar probabilities for all person types.)

To examine individual differences between person types, person types were compared with respect to both scales of the person characteristic questionnaire by means of Tukey honestly significant difference comparisons. To examine individual differences within person types, correlations between the estimated positions of the persons (on the person dimension of the person type to which they belong) and the two scales were calculated (and tested).

Results and discussion

In Table 1, the values of three information criteria are reported for models with 1–4 person types. In this table, it can be seen that two out of the three information criteria have the lowest values for the solution with three person types. On the basis of these results and the good interpretability of the solution, the model with three person types was selected. All this implies that individual differences in situation–behavior profiles for the expression of anger cannot be captured by a single dimension: There are three qualitatively different person types that are characterized by different orderings of the situations and the responses. The estimated proportions of persons belonging to each of the three person types are .37, .34, and .29, respectively.

The estimated positions of the situations for the three person types are reported in the three rightmost columns of Table 2. By construction, the position of the most frustrating situation is zero for each of the three person types; only the differences between the situations can be interpreted in a meaningful way since they are ordered on an interval scale (Fischer, 1995a). In Table 2, it can further be seen that the order of the situations is the same for the three person types and corresponds to the order of the judged persistence of frustration. Furthermore, it can also be seen that the differences between the positions of the situations are much smaller for the first person type than for the second and the third. For example, the difference between the most and the least frustrating situation is only. 89 for the first person type, while this difference is 5.03 and 2.23 for the second and third person type, respectively. This means that there are between-type differences in the degree to which persons differentiate between situations in terms of the amount of angry behavior they elicit. This

Table 1
Values of information criteria (AIC, BIC, CAIC) for mixture distribution Rasch models with one, two, three, and four mixture components

Information criteria	Number of person types			
	1	2	3	4
AIC	10990.67	10682.37	10414.95	10322.60
BIC	11109.18	10923.23	10778.14	10808.13
CAIC	11140.18	10986.23	10873.14	10935.13

Table 2
Positions of the situations in Person Types 1, 2, and 3

Situations	PF	γ_{j1}	γ_{j2}	γ_{j3}
1. As a part of an exam, you have made a paper of 15 pages and gave it to a fellow student who lost it, though. You don't have any copy of it neither on your PC nor a hard copy.	6.60	0.0	0.0	0.0
2. You are having an appointment with a fellow student but he (she) arrives 25 min late saying that he (she) has forgotten it.	4.40	−.58	−2.07	−1.30
3. You are on the way to a seminar and a fellow student accidentally spills a small amount of coffee over your arm.	2.80	−.89	−5.03	−2.23

Note. PF, persistence of frustration in the situation averaged across 10 judges; γ_{j1}, γ_{j2}, and γ_{j3} refer to the positions of the situations in Person Types 1, 2, and 3, respectively.

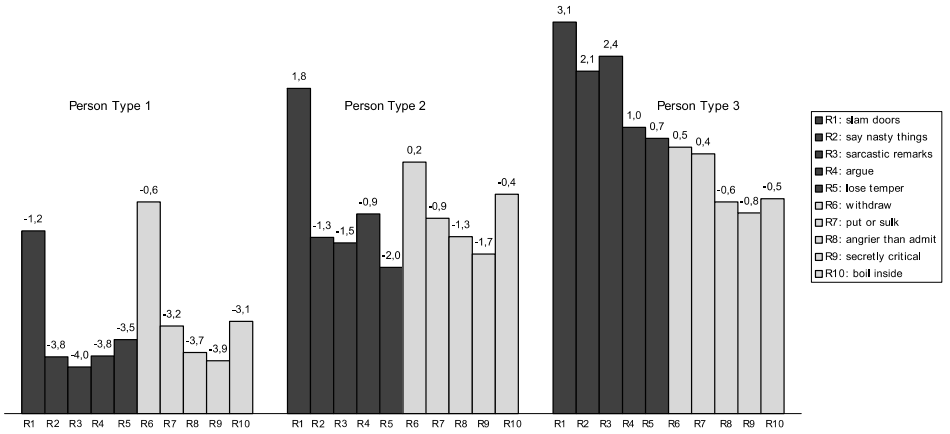


Fig. 7. Response thresholds (values on top of the bars) in the most frustrating situation for anger-out (dark gray) and anger-in (light gray) responses in three person types.

could be linked to the concept of discriminative facility (Mischel, 1981; Cheng, 2003; Chiu, Hong, Mischel, & Shoda, 1995): Persons of Person Type 1 could be assumed either to perceive less accurately the differences between the situations involved or to lack the ability or flexibility to adjust their behavior to situation characteristics.

The positions of the responses (or the response thresholds) for the different person types are shown in Fig. 7.[3] From this figure, it can be seen that the persons of the first person type are characterized by low response thresholds for the anger-in as well as the anger-out responses with exception of the anger-out response 'I do things like slam doors' and the anger-in response 'I withdraw from people'. Tentatively, we label this person type as high anger-out and high anger-in because the persons belonging to it will display a lot of anger-out and anger-in responses. For the second person type,

[3] The positions of the persons θ_{ic} have been parameterized in such a way that the mean position in each class is 0; since, in each class, the position of the most frustrating situation was fixed to 0, the response thresholds are comparable.

the response thresholds of the anger-in and the anger-out responses are about equally high and clearly higher than those of the first person type. Tentatively, this second person type is therefore labeled as moderate anger-out and moderate anger-in. For the persons of the third person type, the most striking finding is that the five anger-in responses have smaller response thresholds than the five anger-out responses. Moreover, the response thresholds of the anger-out responses for this person type are higher than those for the other two person types; this is especially the case for the anger-out response 'I do things like slam doors' and for the verbal anger-out responses 'I say nasty things' and 'I make sarcastic remarks'. Hence, this person type is tentatively labeled as low anger-out and moderate anger-in. It may be noted that the fact that the person type (PT1) has the lowest response threshold is in line with the hypothesis referred to above; in particular, persons of this person type may be conjectured to lack some behavior control ability. Note that the labeling of the person types in high/moderate/low terms is rather coarse and does not capture all qualitative between-person type differences that appear from a close inspection of Fig. 7.

In addition, when only the anger-out responses (ignoring slamming doors which is high in all person types) are examined, another interesting difference between the person types shows up: It is striking that in the high anger-out/high anger-in person type (PT1) the non-verbal anger-out response loosing temper has the highest threshold while the other, verbal anger-out responses have lower thresholds while in the moderate and low anger-out person types (PT2 and PT3), the opposite pattern holds. A plausible explanation for this result may be that persons with high thresholds for anger-out responses have problems with expressing their anger in that they do not easily express their anger but if they do so, they easily lose their temper (while this is, relatively speaking, less the case for the persons of the high anger-out person type (PT1)). Anyhow, these results indicate that in the study of individual differences in anger it may be important to take different modes of expressing anger into account (Deffenbacher, Oetting, Lynch, & Morris, 1996; Siegel, 1986). This part of the results of this study indicates that individual differences in anger are indeed multi-dimensional rather than uni-dimensional in nature, as is the case with other affective construct like, for example, anxiety (Endler et al., 1991; Van Mechelen & Kiers, 1999). The three person types especially differed from one another in terms of their response thresholds indicating that there exist substantial person by response interactions. This finding clearly links up with the finding that anger-in and anger-out responses are not bipolar but constitute different dimensions (Spielberger & Sydeman, 1994).

After estimating the positions of the situations (γ_{jc}) and the response thresholds (δ_{kc}) for the three person types, all subjects were assigned to one of the three person types on the basis of their maximum a posteriori person type membership probability. The numbers of persons assigned to the first, second and third person type are 125, 114, and 99, respectively. All persons are also characterized by a position (θ_{ic}) on the person dimension within the person type to which they belong. Consequently, on the basis of the provided information, it is possible for each person to calculate the probability that he (she) will emit a particular response in a particular situation. For example, if Participant X belongs to Person Type 3 and he (she) has a

score of 2 on the person dimension of this person type ($\theta_{\text{Particpant X, Person Type 3}} = 2$), then the probability that this person will be secretly critical ($\delta_{k3} = -.08$, see Fig. 7) in a situation in which he (she) is having an appointment with a fellow student who arrives 25 min late ($\gamma_{j3} = -1.30$, see Table 2) is 0.69 [$p = \text{logit}^{-1}(2 + (-1.30) - (-.08)) = \text{logit}^{-1}(.78) = .69$].

Next, the three person types were compared with respect to hostile encoding and hostile expectancy. In Table 3, it can be seen that persons of the high anger-in and high anger-out group (Person Type 1) encode interpersonal frustrating situations significantly more in a hostile way than persons of the two other person types. This may explain why they have low thresholds for all responses. Otherwise, the fact that they feel assaulted easily may also account for their relative lack of differentiation between interpersonal frustrating situations. As far as the involved responses may be conceived as coping responses, the fact that the persons of Person Type 1—who do not discriminate well between situations—have low response thresholds for *all* responses may reflect their lack of coping flexibility linking up with Cheng's dual-process model (Cheng, 2003).

With respect to within type person differences, Table 4 presents, for each person type, the correlations across persons between, on the one hand, the estimated positions θ_{ic} of the persons on the person dimension of the person type to which they belong (as estimated on the basis of the situation–response questionnaire) and, on the other hand, hostile encoding and hostile expectancy scores (as obtained from the person characteristic questionnaire). In this table, it can be seen that for each of the three person types the person position significantly and positively correlates with hostile encoding as well as with hostile expectancy. This means that within each person type, persons with a higher position on the underlying dimension encode interpersonal frustrating situations in a more hostile way and expect more negative consequences of expressing their anger. The latter is especially interesting as it means that persons who take higher positions on the underlying dimension and therefore tend to display more easily anger-related responses do *not* so because they expect less negative consequences of expressing their anger. One may note that, in general, relations between on the one hand, between and within person type differences and, on the other hand, external process-related personality characteristics are moderately high at best. In part, the latter may be due to the fact that different persons can

Table 3
Mean scores of three person types on hostile encoding and hostile expectancy

Mean (*SD*)	Type 1 High anger-out High anger-in	Type 2 Moderate anger-out Moderate anger-in	Type 3 Low anger-out Moderate anger-in	$F(2, 335)$
Hostile encoding	25.59_{a} (7.14)	22.14_{b} (7.13)	21.31_{b} (6.93)	11.93*
Hostile expectancy	28.30_{a} (6.52)	28.32_{a} (5.82)	27.82_{a} (6.81)	0.21

Note. Means in the same row that do not share the same subscript differ at $p < .05$ in the Tukey honestly significant difference comparison.

* $p < .01$.

Table 4
Correlations between person type-specific position (θ_{ic}) of the persons and hostile encoding respectively hostile expectancy within each of three person types

Person type	n	Hostile encoding	Hostile expectancy
1	125	0.29**	0.31***
2	114	0.40***	0.44***
3	99	0.34***	0.28**

Note. n, number of persons belonging to the person type.
** $p < .01$.
*** $p < .001$.

be characterized by the same situation–behavior profile on the basis of different underlying psychological processes.

General discussion

In this paper, a methodology was proposed that takes the full personality triad into account as demonstrated in an empirical study on anger. Results of the latter indicated that individual differences in anger cannot be grasped in terms of a simple additive model assuming a homogeneous population and a single underlying dimension for persons, situations and responses. From our analysis based on an alternative method, qualitatively different person types showed up, which differed in terms of their ability to discriminate between anger-provoking situations, and in terms of qualitatively different response thresholds. Note that the structural mechanism in terms of discriminative facility and response thresholds that we were able to reveal through our approach clearly goes beyond purely descriptive approaches proposed earlier, including our own TTM (Vansteelandt & Van Mechelen, 1998). Note further that our approach allows one to relate both between and within person type differences to external variables; as such, in our empirical study, both types of differences appeared to be related to differences in hostile encoding tendency whereas within type differences, in addition, were also related to hostile expectancy processes.

The models we presented allow one to represent quantitative and/or qualitative individual differences in situation–behavior profiles. As such, the models include categorical as well as dimensional aspects, and touch upon the discussion within the personality domain on "carving nature at its joints" and on differences in kind or degree (De Boeck, Wilson, & Acton, 2003; Gangestad & Snyder, 1985; Haslam & Kim, 2002; Meehl, 1992). Within this context, one may wonder whether our methodologies allow the researcher to identify real person types as occurring in nature. Two important observations are to be made with regard to this question. On the one hand, the question should be answered negatively: the models we proposed may be conceived as glasses through which one may look at some psychological reality; any conclusions that are drawn are being made conditionally on the glasses that have been chosen and should not be un-

derstood in an absolute manner. On the other hand, the models we proposed may be conceived as very broad and flexible tools to represent the data: They allow the existence of one, two or more person types; within each person type, quantitative individual differences may or may not exist (i.e., all persons may be located on different or the same position on the person dimension); between person types, quantitative as well as qualitative individual differences may or may not exist. In this regard, it is important to emphasize that the selection of the final model out of the broad range of possibilities is ultimately dictated by nature, that is by the empirical gathered data set under study. For example, in our application, it was possible, in principle, that the data would have favored a model (1) with a single person type only.

Regarding model selection, it is important to emphasize that this selection is to be based on both statistical criteria (e.g., information criteria) as well as on substantial theoretical interpretations. In this respect, firstly, it may be noted that the outcome of statistical criteria will be influenced by the sets of persons, situations, and responses as chosen by the researcher. For example, when the researcher selects only extreme situations (e.g., a very frustrating vs. a neutral one) and responses (e.g., actually hitting someone vs. feeling a little bit tense) a uni-dimensional model with no or only small individual differences would probably apply, because the order of the situations and the responses will probably be the same for all persons. In this case, the predictive power of the situations and the responses will be very strong (Mischel, 1999). However, when the sample of situations and/or responses is more ambiguous, the probability will increase that the order of the situations and the responses will differ across person types and that, as a result, a multidimensional Model (2) will apply. The latter implies that qualitative (or multidimensional) individual differences in situation–behavior profiles have the highest probability of showing up in ambiguous situations and/or with respect to responses that allow response freedom to a strong extent.

Secondly, it may also be noted that after a model is selected, this choice may be further justified by looking for additional, converging empirical evidence; this may be done by relating the estimated types or person positions on a dimension to (structural or process-related) external information, as demonstrated in this study. For example, in the application above, part of the differences between person types could be linked to the concepts of hostile attribution bias (Dodge, 1993; Zelli & Dodge, 1999) and hostile expectancy. In correspondence with Zelli and Dodge (1999) high anger-out persons (Person Type 1) more easily encoded aversive interpersonal situations in a hostile way in comparison to the other person types; further, within all three person types, it seems to be the case that persons foresee but dismiss the negative sanctions aggression may lead to because the persons displaying most angry behavior did expect more negative consequences of expressing it. In addition, other potentially relevant processes—on which we did not collect data—may play an important role as well.

From a formal point of view, as mentioned before, Model (1) and Model (2) are both logistic regression models. However, they go beyond the standard logistic regression model with a binary criterion and a set of binary (or continuous) predictors

in two respects: (a) Model (1) is a multilevel logistic regression model with a random intercept for the persons and dummy predictors for situations and responses, (b) Model (2) is a discrete mixture of Model (1)'s, which means that it is assumed that it implies a finite number of subpopulations (which are not known beforehand) to each of which a distinctive Model (1) applies. A first major advantage of Model eqs. (1) and (2) is that they allow the researcher to explore person × situation × response data without relying (in a first stage) on external predictor variables (like hostile encoding, level of frustration of the situation in general, anger-in, and so forth); as a consequence, these models make it possible to examine the personality triad within a behavioral domain in an exploratory way, without requiring clear a priori knowledge about relevant involved person, situation and response features. An additional advantage of Model (2) is that this model, unlike a standard logistic regression model (as well as unlike various non-additive models), is well-suited to study complex person by situation and/or person by response interactions in an insightful and parsimonious way (e.g., without a need to include a huge amount of additional predictors, which may readily lead to unsolvable estimation and identification problems). Note in this respect that especially the typological approach as implied by Model (2) considerably contributes to the parsimony with which interactions can be captured. Formally speaking, dimensional alternatives could be considered for Model (2), but the latter, too, may quickly end up in unsolvable estimation problems, whereas models such as Model (2) have been shown to constitute a neat and feasible alternative (Rijmen & De Boeck, 2002).

We conclude that the models as presented in this paper are a promising tool to study individual differences in situation–behavior profiles; as such they may make the complex interplay of persons, situations, and responses amenable to empirical research and they may help to truly understand what in the person interacts how with what in the situation (Pervin & John, 1997). It should be clear that our approach requires a careful, theoretical as well as empirical, study of the personality triad. As such, its ultimate goal is not the derivation of a small number of person types or dimensions but rather the deeper understanding of personality.

Appendix A

To give a formal account of the uni-dimensional Model (1) for individual differences in situation–behavior profiles, it is assumed that three-way, three-mode person × situation × response data are available that indicate whether person i $(1,\ldots,i,\ldots,N_{\mathrm{p}})$ displays response k $(1,\ldots,k,\ldots,N_{\mathrm{r}})$ in situation j $(1,\ldots,j,\ldots,N_{\mathrm{s}})$ or not; $X_{ijk}=1$ when person i displays response k in situation j and $X_{ijk}=0$ otherwise.

In Model (1), persons are characterized in terms of their position θ_i $(\theta_1,\ldots,\theta_i,\ldots,\theta_{N_{\mathrm{p}}})$, situations by their position γ_j $(\gamma_1,\ldots,\gamma_j,\ldots,\gamma_{N_{\mathrm{s}}})$ and responses by their thresholds δ_k $(\delta_1,\ldots,\delta_k,\ldots,\delta_{N_{\mathrm{r}}})$. The uni-dimensional Model (1) can be written as follows:

$$\text{logit } P(X_{ijk}=1/\theta_i)=[(\theta_i+\gamma_j)-\delta_k]. \tag{A.1}$$

Model (A.1) is a special case of an existing Item Response Theory (IRT) model, namely the Linear Logistic Test Model (LLTM) (Fischer, 1995a), which itself is a restrictive form of the Rasch model (Fischer, 1995b); in our case, each situation–response combination jk is considered as one item. The Rasch model can be written as follows:

$$\text{logit } P(X_{ijk} = 1/\theta_i) = [\theta_i - \beta_{jk}] \tag{A.2}$$

with β_{jk} a difficulty parameter for each situation–response combination jk. Model (A.1) implies the following linear restriction on the difficulty parameters β_{jk} of model (A.2):

$$\beta_{jk} = -\gamma_j + \delta_k + \alpha_0 \tag{A.3}$$

with α_0 being a normalization constant. The number of situation parameters γ_j is $(N_s - 1)$ and the number of response parameters δ_k is $(N_r - 1)$, resulting in $[(N_s + N_r) - 2]$ parameters; this number corresponds to the rank of the linear system (A.3).

Appendix B

The multidimensional Model (2) as proposed in this paper comes down to a Mixture Distribution Linear Logistic Test Model with model (A.1) being applicable in each of the C mixture components (for an account of this model in another context, see Mislevy & Verhelst, 1990). Formally, Model (2), which implies C classes of persons, can be written as follows:

$$P(X_{ijk} = 1/\theta) = \sum_{c=1}^{C} \pi_c \text{ logit}^{-1}[(\theta_{ic} + \gamma_{jc}) - \delta_{kc}]. \tag{B.1}$$

In (B.1) π_c is the prior probability that a person belongs to class c (this can be seen as a reflection of the proportion of persons belonging to the cth class); θ_{ic} denotes the position of person i on the dimension of class c; γ_{jc} denotes the position of situation j on the situation dimension of class c; δ_{kc} refers to the threshold of response k in class c. Like model (A.1) is a restrictive variant of the Rasch model (A.2), model (B.1) is a restrictive variant of a Mixture Distribution Rasch Model (MDRM) (Rost, 1990) for person by item data, with each situation-response combination being considered as one item. The MDRM reads as follows:

$$P(X_{ijk} = 1/\theta) = \sum_{c=1}^{C} \pi_c \text{ logit}^{-1}(\theta_{ic} - \beta_{jkc}) \tag{B.2}$$

with β_{jkc} being the difficulty parameter of situation–response combination jk in class c. The linear restriction that is imposed in model (B.1) on the difficulty parameters β_{jkc} of model (B.2) is analogous to the linear restriction in equation (A.3) and can be written as follows:

$$\beta_{jkc} = -\gamma_{jc} + \delta_{kc} + \alpha_{0c}. \tag{B.3}$$

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