The enriched behavioral prediction equation and its impact on structured learning and the dynamic calculus

Raymond B. Cattell
University of Hawaii

Gregory J. Boyle
Bond University, Gregory_Boyle@bond.edu.au

David Chant
Queensland Centre for Schizophrenia Research

Follow this and additional works at: http://epublications.bond.edu.au/hss_pubs

Recommended Citation
Raymond B. Cattell, Gregory J. Boyle, and David Chant. (2002) "The enriched behavioral prediction equation and its impact on structured learning and the dynamic calculus".

http://epublications.bond.edu.au/hss_pubs/42
The Enriched Behavioral Prediction Equation and Its Impact on Structured Learning and the Dynamic Calculus

By Raymond B Cattell, Gregory J Boyle and David Chant

Raymond B. Cattell, Department of Psychology, University of Hawaii; Gregory J. Boyle, Department of Psychology, Bond University, Gold Coast, Australia, and Department of Psychiatry, University of Queensland, Brisbane, Australia; David Chant, Queensland Centre for Schizophrenia Research, Brisbane, Australia. Raymond B. Cattell died in Honolulu on February 2, 1998. Professor Cattell was one of the most prolific contributors to the scientific analysis of personality during the 20th century and was ranked among the most highly cited psychologists of all time (along with Sigmund Freud, Jean Piaget, and Hans Eysenck).

Correspondence concerning this article should be addressed to Gregory J. Boyle, School of Humanities and Social Sciences, Bond University, Gold Coast, Queensland 4229, Australia. Email: greg.boyle@bond.edu.au

Abstract:

This theoretical note describes an expansion of the behavioral prediction equation, in line with the greater complexity encountered in models of structured learning theory (R. B. Cattell, 1996a). This presents learning theory with a vector substitute for the simpler scalar quantities by which traditional Pavlovian-Skinnerian models have hitherto been represented. Structured learning can be demonstrated by vector changes across a range of intrapersonal psychological variables (ability, personality, motivation, and state constructs). Its use with motivational dynamic trait measures (R. B. Cattell, 1985) should reveal new theoretical possibilities for scientifically monitoring change processes (dynamic calculus model; R. B. Cattell, 1996b), such as encountered within psychotherapeutic settings (R. B. Cattell, 1987). The enhanced behavioral prediction equation suggests that static conceptualizations of personality structure such as the Big Five model are less than optimal.

The behavioral prediction equation that derives from the specification equation of factor analysis (measurement model in structural equation models; see McArdle & Cattell, 1994) was formulated by Cattell (1979, 1980) for estimating the combined effects of intrapersonal psychological variables on behavioral/learning outcomes/gain. Such constructs include relatively enduring ability and personality traits, dynamic (motivation) traits, and situationally sensitive/transitory mood states. The behavioral equation theoretically allows us to anticipate observable behaviors as a direct function of underlying factors/latent trait constructs. In its most parsimonious form, a linear-additive model is proposed (Equation 1), although less likely nonlinear/multiplicative relationships also have been considered (Cattell, 1983). Application of structured learning theory extends prediction beyond the traditional Pavlovian–Watsonian–Skinnerian learning theory (cf. Boyle, Stankov, & Cattell, 1995; Cattell, 1996b), enabling measurement of dynamic learning change as a vector quantity rather than scalar change only in strength of response (cf. Cattell, 1990, p. 103). The simplified general form of the well-established state–trait behavioral equation is

\[ \omega_{ij} = \sum h_{pi} T_i + \sum f_{pi} S_i + \theta, \]  

(1)
where $T$ represents traits, $S$ represents states, and the response act $a_{hijk}$ is multifactorially determined. Here, the traits, which account for up to 60% of the predictive variance, and states, which may account for a further 20% to 25% of the predictive variance (see Boyle, 1988), are included as scores on common factors (in factor analytically derived instruments such as the Sixteen Personality Factor Questionnaire [16PF] and the Eight State Questionnaire, respectively). The unique variance (accounting for as much as 20% of predictive variance) is denoted by $u^2$ in standard factor analytic textbooks (e.g., Cattell, 1978; Comrey & Lee, 1995; Gorsuch, 1983). The traits can be divided more specifically into cognitive abilities, relatively stable (normal and abnormal) personality traits, as well as less stable dynamic motivation traits, including both innate biological drives/ergic factors and culturally acquired (socially conditioned) sentiment factors (Cattell, 1985). The behavior indices ($b_s$), obtained as loadings from the factor pattern matrix of an appropriately executed factor analysis, provide quantitative estimates of the contributions from the separate latent traits. The behavior indices are peculiar to the focal stimulus ($h$), the form of the response ($j$), and the ambient/background situation ($k$). The global situation comprises both the focal stimulus and the ambient situation. The subscript $i$ indicates the magnitude of a particular individual’s response act and observed score on the particular trait or state measure.

Previously, the state provocation ambient/background situation was located under the state terms only, denoting the situational sensitivity of transitory emotional states. However, situational sensitivity is also seen in relation to dynamic motivational traits and in trait change factors, which emerge from differential (dR factoring) of trait difference scores obtained in repeated measures designs (see Boyle, 1987; Boyle & Cattell, 1984). Traits are only relatively stable, and the ambient situation influences both trait and state dimensions. Thus, trait and state levels are augmented by their situational sensitivity to the ambient situation, represented by $skt$ and $sks$, respectively. Here, the loading can be split into perception of the stimulus and the augmentation, which the trait gives to the strength of the response. A further major construct pertains to cognitive processing (distinct from abilities). However, there has been a relative paucity of multivariate psychometric research into this cognitive information processing construct, estimated, for example, by a diversity of elementary cognitive tasks (see Stankov, Boyle, & Cattell, 1995). It appears as an image in the broadest sense (iconic or echoic; see Schwartz & Reisberg, 1991) by conscious and unconscious processes not previously incorporated into the behavioral equation. However, unlike transient states, more enduring latent traits may exhibit steady long-term maturational/learning tendencies.

To provide a brief empirical illustration of structured personality learning (avoiding the added complexity of the cognitive information processing term), a sample of 30 items from Form A of the 16PF (Factors B, C, and E) was divided into four-item parcels per factor (comprising three to four items each), thereby giving a total of 12 marker variables. The 30 items were administered to a sample of 92 undergraduates on two separate occasions 1 month apart, allowing a quantitative assessment of the changes postulated within structured learning theory. Notwithstanding the limitation that other unmeasured variables might also have influenced the obtained change scores, the learning experience was defined simply as “1 month of university life” for the purpose of the present explication.
For the first measurement occasion (baseline prelearning data) the 12 x 12 intercorrelation matrix was subjected to a methodologically appropriate iterative, maximum-likelihood factor analysis with rotation to direct oblimin simple structure by means of SPSS (cf. Cattell, 1978; Comrey & Lee, 1995; Gorsuch, 1983). The same procedure was used on the postlearning data, enabling comparison of pre- and postlearning scores (changes to personality trait structures). Discounting extraneous variables, the empirically obtained difference scores represent the changes resulting from structured personality learning, suggesting that personality structure itself is amenable to learning. Provided the two-factor pattern solutions are rotated to the same position (i.e., to maximum agreement of the postlearning factor pattern with the prelearning factor pattern), the factors can be regarded as essentially the same in each instance (ensuring the same factors at test and retest). The differences in magnitude of loadings show the learning gain to personality structures; thus,

\[ r_{2.1} - \sqrt{r_{1.1}^2 - r_{1.2}^2}. \]

Substituting the empirically obtained factor loadings for each of the 12 variables into the corresponding factor equations gives us Table 1. We now consider the first variable for each of the three factors. For example, the learning gain \((r_{E_1})\) on Factor C (Ego Strength) should show what the experience has done to the involvement of Ego Strength and so on.

Table 1. Pre- and Postlearning Factor Pattern Loadings for Each Item Parcel Variable

<table>
<thead>
<tr>
<th>Item parcel</th>
<th>Factor 1: Ego Strength</th>
<th>Factor 2: Dominance</th>
<th>Factor 3: Intelligence</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_1</td>
<td>.64</td>
<td>.20</td>
<td>.05</td>
</tr>
<tr>
<td>V_2</td>
<td>.54</td>
<td>.30</td>
<td>.24</td>
</tr>
<tr>
<td>V_3</td>
<td>.52</td>
<td>.00</td>
<td>-.36</td>
</tr>
<tr>
<td>V_4</td>
<td>.57</td>
<td>-.73</td>
<td>-.01</td>
</tr>
<tr>
<td>V_5</td>
<td>-.33</td>
<td>.06</td>
<td>.25</td>
</tr>
<tr>
<td>V_6</td>
<td>.20</td>
<td>-.12</td>
<td>.27</td>
</tr>
<tr>
<td>V_7</td>
<td>.11</td>
<td>.05</td>
<td>.45</td>
</tr>
<tr>
<td>V_8</td>
<td>.05</td>
<td>.19</td>
<td>-.16</td>
</tr>
<tr>
<td>V_9</td>
<td>-.77</td>
<td>.29</td>
<td>.09</td>
</tr>
<tr>
<td>V_10</td>
<td>-.38</td>
<td>.25</td>
<td>-.03</td>
</tr>
<tr>
<td>V_11</td>
<td>-.18</td>
<td>.12</td>
<td>-.11</td>
</tr>
<tr>
<td>V_12</td>
<td>-.08</td>
<td>.76</td>
<td>-.11</td>
</tr>
</tbody>
</table>

Note. Changes in factor loadings for each factor are shown in boldface. Item parcels \(V_1\) to \(V_9\) measure Sixteen Personality Factor Questionnaire (16PF) Factor C (Ego Strength); Item parcels \(V_{10}\) to \(V_{18}\) measure 16PF Factor E (Dominance); Item parcels \(V_{19}\) to \(V_{24}\) measure 16PF Factor B (Intelligence).

Table 1 reveals that the effects of 1 month of university life have produced a discernible increase in Ego Strength but no significant changes in either Dominance (Factor E) or Intelligence (Factor B). This finding suggests that personality structures may change as a direct function of learning experiences (cf. Boyle & Cattell, 1987). Structured learning theory is consonant with other empirical findings. The most
obvious example is Block’s extensive research into the longitudinal development of ego strength, which provides evidence of learning experiences influencing personality structure (e.g., Block, 1993; Westenburg & Block, 1993). Consequently, structured learning is compatible with longitudinal research findings external to the Cattellian school.

Other approaches to the analysis of changes in factor loadings may have some advantages, such as Nesselroade and Molenaar’s (1999) sophisticated procedures for multivariate time-series, dynamic factor analysis (see also Molenaar, 1985, 1994). To analyze more closely the changes in the factor loadings presented in Table 1, the present empirical data set was also subjected to further analysis using PROC CALIS in SAS (Version 7). A standard longitudinal confirmatory model with three congeneric factors on each measurement occasion was tested, with each factor loading on the corresponding 16PF item parcels. For the longitudinal factor analysis, the overall chi-square was 259.91 (with 233 degrees of freedom), the root-mean-square error of the approximation (RMSEA) estimate was 0.04, and RMSEA 90% upper confidence limit was 0.06, indicating a high degree of fit of the three factors across both measurement occasions. Furthermore, tests of invariant loading patterns (principled significance tests) revealed that the changes across measurement occasions were slight, $\Delta^2(6) = 11.74, p = .07$. Thus, although changes in personality structure may occur over time (see Table 1), such changes may be small in magnitude.

In a further elaboration of the behavioral equation, modulation theory proposes that each individual has a characteristic susceptibility or liability to react with a particular emotion and that every ambient situation has an idiosyncratic provocative power, or modulating index ($sAx$), to elicit a particular state ($x$). Our modulator model supposes that, instead of a simple additive action, there is a synergistic influence of the modulator on the liability. Thus, in line with Cattell (1996b), there is an entirely novel expansion of fluctuating/transitory mood states,

$$S_{iAx} = s_{Ax}L_{iAx}$$

(3)

wherein $L_{iAx}$ represents an individual’s liability to the temporary state. For a given ambient situation, one could estimate an individual’s ($i$) momentary level on state ($x$), as the product of the modulating power of ambient situation on state, and the person’s liability. Thus,

a file of ambient situation indices, the $s$’s, can be built up by research for the most common life situations, and similarly, a personnel file of individual liabilities, the $L$’s, can be preserved from previous testing, just like a set of trait scores. For liability to this and that emotion is once more a trait characteristic of the individual . . . and can be measured and recorded in a personality profile file, like any other trait. . . . the product of $s$ and $L$ will result in the state factor $S$ . . . having a different variance from one ambient situation to another, according to the $s_k$ value. (Cattell, 1979, p. 192)

Inclusion of the state liability term $s_kL_{iAx}$ into the behavioral prediction equation may enable us to move more clearly to structured learning theory (Cattell, 1996b). The perception of the stimulus and augmentation values (Cattell, 1996a) are first obtained by exploratory factor analysis as behavior indexes. The traits and especially the states
may also be expected to change somewhat in magnitude across measurement occasions. Thus, the learning experience results in changes on all members of Equation 1, namely perception, augmentation, trait, and state. This vector change is particularly important in the dynamic motivation realm (Boyle, 1988; Cattell, 1985). It implies that a learning experience not only increases the strength of an attitude or skill but also changes the mode of satisfaction obtained by it, information that is particularly important in clinical practice (Cattell, 1987). Structured learning also introduces us to the whole field of the dynamic calculus theory (Cattell, 1985, 1992, 1996b). We have thus reached what might be figuratively referred to as a “psychometric psychoanalysis” (Cattell, 1987).

**Conclusions**

The present theoretical note expands on Cattell’s structured learning theory and on traditional Pavlovian–Skinnerian models. Psychological theorizing has recognized that exposure to situational learning experiences facilitates development of increasingly complex cognitive structures (schemata). The current brief empirical illustration supports the prediction that novel learning experiences may also facilitate changes in personality structure.

The enriched behavioral prediction equation, although currently a largely theoretical statement, provides the field of personality psychology with a valuable antidote to atheoretical models such as the currently popular Big Five, in which dynamic personality structure is conceived simply as a set of static dispositional tendencies not influenced by social experience. Indeed, as Block (1995, p.188) pointed out, “no functioning psychological ‘system,’ with its rules and bounds, is designated or implied by the ‘Big Five’ formulation; it does not offer a sense of what goes on within the structured, motivation-processing, system-maintaining individual.” In contrast to the Big Five and similar models, it is evident that personality traits exhibit only relative stability across time.

In conclusion, the current article sets forth a brief illustration of how psychological theory can incorporate multivariate ability and personality measurement (cf. Boyle, 1991), in addition to situational analysis, into the prediction of human behavior. The enriched behavioral prediction equation may also be expected to serve as a frame of reference to guide the currently very active development of different forms of dynamic factor analysis (see Molenaar, 1985, 1994; Nesselroade & Molenaar, 1999); To be sure, the details still remain to be filled in, but “the navigator’s course has been charted.”

**References:**


