



Commentary

Personality structure and measurement: The contributions of Raymond Cattell

William Revelle*

Northwestern University, Evanston, Illinois, USA

Raymond Cattell's influence on the field of personality is hard to overstate. With over 8,900 citations to his lifetime work, and an 'h rating' of 40, his contributions continue to be well recognized. His productivity was amazing. In the 18 years before he wrote the target article (Cattell, 1946b), he had already published at least 62 articles or books, with at least another 414 to go. Of his articles in the *British Journal of Psychology* (*BJP*), two in 1946 had the same goal: outlining a broad program of research into the structure and measurement of personality (Cattell, 1946c, 1946b). In that same year, he elaborated on these ideas in yet one more of what would become his 55 books (Cattell, 1946a). To understand the target article, it is important to understand both of his articles in *BJP* that year as well as the context of his research.

Cattell in context

Cattell finished his Ph.D, with Spearman in 1929 (with advice from Fisher and Burt) and after several years went on to work with Thorndike. This early training in factor analysis of intelligence tests would guide his thinking for the rest of his life. Although, he continued to study intelligence, he would later apply factor analytic techniques to the study of personality as well. When he wrote these two papers for *BJP*, Cattell had just finished three years at Harvard where his colleagues included Allport, Murray, and White. Allport had recently published his text on personality (Allport, 1937) and Murray had finished *Explorations in Personality* (Murray, 1938). In 1945, Cattell left Harvard to go to the University of Illinois where he could use the new computing facilities to do large-scale factor analyses of personality and ability measures. His goal was to apply quantitative methods to personality in order to derive the psychological equivalent of the Mendeleev table.

Two contributions of his first *BJP* article in 1946 (Cattell, 1946c) were (a) distinguishing between *surface* and *source* traits and (b) the introduction of the *data*

* Correspondence should be addressed to William Revelle, Department of Psychology, Northwestern University, Evanston, IL, USA 60208 (e-mail: revelle@northwestern.edu).

box. These ideas are so well established today that it is hard to believe they were ever new or controversial. In his second article, Cattell (1946b) tried to integrate the study of dynamic, temperamental, and ability traits into one framework. In both of these articles, as well as much of his other work, he was ‘an explorer on the run’ (Goldberg, 1968), outlining programs of research for others to fill in. Unfortunately, as is true for many early explorers moving rapidly through uncharted territories, some of his maps included features that are as hard to find today as El Dorado.

The operational determination of trait unities (Cattell, 1946c)

Surface traits were seen as clusters of observed correlations (e.g. self reports of anxiety, crying, and depression) while source traits were equated with factors (derived from factor analysis) thought to be causes (e.g. Spearman’s ‘g’, Burt’s factors of ‘emotionality’) of the observed correlations. This distinction between observed (surface) and latent (source) variables, while perhaps controversial in the heyday of behaviourism, has blossomed into a number of areas, variously labelled factor, path, and structural equation modelling (Loehlin, 2004, McArdle, 1984), latent class analysis (Lazarsfeld & Henry, 1968), item response theory (Embretson & Reise, 2000) and latent growth modelling (McArdle & Bell, 2000). Indeed, it is difficult to conceive of modern analysis without the use of latent variables. (The history of surface and source traits goes back, of course, far beyond Cattell (1946c) and can be seen in Plato’s allegory of the cave where surface traits are mere shadows on the wall representing the unseen but causal sources).

To Cattell the proper level of analysis were source traits, for these could then be decomposed into ‘constitutional’ and ‘environmental mould’ traits. This distinction has continued in behaviour genetics with the decomposition of phenotypic variance components associated with additive, dominance, and epistatic genetic effects as well as shared, and unique environmental components.

Cattell (1946c) recognized that the source factors derived from factor analysis had an ‘Achilles heel’ due to the infinity of possible rotations for each solution. Although, favourably disposed to the simple structure argument of Thurstone (1947), he emphasized factorial replication across different samples and mixes of variables and proposed the ‘principle of parallel proportional profiles’. Sadly, this suggestion has not been as widely adopted as has Thurstone’s concept of simple structure. With the introduction of such methods as confirmatory factor methods to study factorial invariance (Millsap, 2007) it is now possible to take advantage of the emphasis upon replication Cattell (1946c) proposed.

The *data box* emphasized that we are not limited to correlating tests over people at one time. In its 1946 formulation, there were six ‘designs of covariation using literal measurement’ and 12 ‘designs of covariation using differential or ratio measurement’ (Cattell, 1946c, p 94–95). Considering Persons, Tests, and Occasions as the fundamental dimensions, it was possible to generalize the normal correlation of Tests over Persons design (R analysis) to consider how Persons correlated over Tests (Q analysis), or Tests over Occasions (P analysis), etc. Cattell (1966) extended the data box’s original three dimensions to five by adding Background or preceding conditions as well as Observers (see also Cattell (1977)). Applications of the data box concept have been seen throughout psychology, but the primary influence has probably been on those who study personality development and change over the life span (McArdle & Bell, 2000, Mroczek, 2007, Nesselrode, 1984). Unfortunately, even for the original three dimensions, Cattell (1978) used a different notation than he did in Cattell (1966, 1977) or Cattell (1946b).

More recently, the data box concept has been applied to the study of how individuals differ in the *within* individual structure of personality states and emotions over time (Feldman, 1995, Fleeson, 2007, Rafaeli, Rogers, & Revelle, 2007). That is, by finding the within subject correlation of different affects over time (P analysis), and then correlating the within individual factor loadings across subjects (R analysis), it is possible to better understand how people may be described in terms of their unique affective structure. These three-way models may be done using multi-level modelling techniques that model within subject structure at one level and between level differences at another level, or by taking advantage of three mode factor analysis (Kroonenberg & Oort, 2003) or individual differences in multidimensional scaling programs such as INDSCAL (Carroll & Chang, 1970) specifically designed to treat *N*-way data box problems.

The determination and utility of trait modality (Cattell, 1946b)

Cattell's second *BJP* article in 1946 continued his discussion of personality structure and measurement and attempted to organize the meaning of traits (Cattell, 1946b). The thrust of the argument is that it is possible to divide traits into those that reflect abilities, those that are dynamic, and those that are stable temperaments. Ability traits are all positively correlated and are sensitive to differences in task difficulty and at low difficulty levels, to incentives. Dynamic traits may be measured as responses to cues for reward and punishment, and temperamental traits were what was left over when the other two are removed.

Unfortunately, this partitioning is not as simple as it would appear. The discussion of ability traits and task complexity foreshadowed later developments in item response theory (Embretson & Reise, 2000, Lord & Novick, 1968, Rasch, 1980) with its emphasis upon item complexity (difficulty) tailored to the individual. Cattell (1946b) assumed that ability measures are given at such high levels of motivation that the 'slight differences in concentration are not enough to affect performance'. He seems to have assumed that motivation would have a negatively accelerating positive effect on performance. Unfortunately, this assumption is called into question by demonstrations that variations in (e.g.) energetic arousal associated with diurnal rhythms or stimulants such as caffeine can have a detrimental effect on cognitive performance for subjects who are already highly energized (Revelle, 1993, Revelle, Amaral, & Turriff, 1976, Revelle, Humphreys, Simon, & Gilliland, 1980).

The interplay between ability (what one can do) and temperamental traits (what one normally does) is even more complicated than just affecting high level performance. People systematically differ in their interests and engagement in intellectual activities (Ackerman, 1997, Ackerman & Heggstad, 1997). The dimensions variously labelled as 'openness' or 'typical intellectual engagement' reflect the cognitive activities people prefer to do rather than what they can do. In addition, although, general knowledge is a useful marker of ability, there are also independent contributions of such non-cognitive traits as openness, extraversion, and neuroticism (Chamorro-Premuzic, Furnham, & Ackerman, 2006).

My colleagues and I have been attempting to organize the surface traits one observes in most personality studies into a set of source traits somewhat different from the tripartite divisions of Cattell (1946b). We are attempting to organize personality in terms of what people feel (Affect), what they do (Behaviour), how they think and what they believe (Cognition), and what they want (Desire) (Ortony, Norman, & Revelle, 2005,

Revelle, Wilt, & Rosenthal, 2009, Wilt & Revelle, 2009). However, it remains clear that even after 62 years, a proper understanding of the structure of personality requires considering the issues raised by Cattell in his 1946 articles in the *BJP*.

References

- Ackerman, P. L. (1997). Personality, self-concept, interests, and intelligence: Which construct doesn't fit? *Journal of Personality*, *65*(2), 171–204.
- Ackerman, P. L., & Heggstad, E. D. (1997). Intelligence, personality, and interests: Evidence for overlapping traits. *Psychological Bulletin*, *121*(2), 219–245.
- Allport, G. W. (1937). *Personality; a psychological interpretation*. New York: H. Holt and Company.
- Carroll, J. D., & Chang, J. J. (1970). Analysis of individual differences in multidimensional scaling via an N-way generalization of 'Eckart-Young' decomposition. *Psychometrika*, *35*, 283–319.
- Cattell, R. B. (1946a). *Description and measurement of personality*. Oxford, England: World Book Company.
- Cattell, R. B. (1946b). Personality structure and measurement. II. The determination and utility of trait modality. *British Journal of Psychology*, *36*, 159–174.
- Cattell, R. B. (1946c). Personality structure and measurement. I. The operational determination of trait unities. *British Journal of Psychology*, *36*, 88–102.
- Cattell, R. B. (1966). The data box: Its ordering of total resources in terms of possible relational systems. In R. B. Cattell (Ed.), *Handbook of multivariate experimental psychology* (pp. 67–128). Chicago, IL: Rand-McNally.
- Cattell, R. B. (1977). The grammar of science and the evolution of personality theory. In R. B. Cattell & R. M. Dreger (Eds.), *Handbook of modern personality theory* (pp. 3–42). New York: Wiley/Halsted Press.
- Cattell, R. B. (1978). *The scientific use of factor analysis*. New York: Plenum Press.
- Cattell, R. B. (2009). Personality structure and measurement II: The determination and utility of trait modality. *British Journal of Psychology*, *100*, 233–248, (Reprinted from *The British Journal of Psychology* (1946), *36*, 159–174).
- Chamorro-Premuzic, T., Furnham, A., & Ackerman, P. L. (2006). Ability and personality correlates of general knowledge. *Personality and Individual Differences*, *41*(3), 419–429.
- Embretson, S. E., & Reise, S. P. (2000). *Item response theory for psychologists*. Mahwah, NJ: Erlbaum.
- Feldman, L. A. (1995). Valence focus and arousal focus: Individual differences in the structure of affective experience. *Journal of Personality and Social Psychology*, *69*, 153–166.
- Fleeson, W. (2007). Studying personality processes: Explaining change in between-persons longitudinal and within-person multilevel models. In R. W. Robins, R. C. Fraley, & R. F. Krueger (Eds.), *Handbook of research methods in personality psychology* (pp. 523–542). New York: Guilford Press.
- Goldberg, L. R. (1968). Explorer on the run. (A review of R. B. Cattell, & F. W. Warburton, objective personality and motivation tests: A theoretical introduction and practical compendium). *Contemporary Psychology*, *13*(12), 617–619.
- Kroonenberg, P. M., & Oort, E. J. (2003). Three-mode analysis of multimode covariance matrices. *British Journal of Mathematical and Statistical Psychology*, *56*(2), 305–335.
- Lazarsfeld, P. F., & Henry, N. W. (1968). *Latent structure analysis*. New York: Houghton, Mifflin.
- Loehlin, J. C. (2004). *Latent variable models: An introduction to factor, path, and structural equation analysis* (4th ed.). Mahwah, NJ: Erlbaum.
- Lord, F. M., & Novick, M. R. (1968). *Statistical theories of mental test scores*. Reading, MA: Addison-Wesley.
- McArdle, J. J. (1984). On the madness in his method: R. B Cattell's contributions to structural equation modeling. *Multivariate Behavioral Research*, *19*(2-3), 245–267.

- McArdle, J. J., & Bell, R. Q. (2000). Recent trends in modeling longitudinal data by latent growth curve methods. In T. D. Little, K. U. Schnabel, & J. Baumert (Eds.), *Modeling longitudinal and multiple-group data: practical issues, applied approaches, and scientific examples* (pp. 69-107). Mahwah, NJ: Erlbaum.
- Millsap, R. (2007). Invariance in measurement and prediction revisited. *Psychometrika*, 72(4), 461-473.
- Mroczek, D. K. (2007). The analysis of longitudinal data in personality research. In R. W. Robins, R. C. Fraley, & R. F. Krueger (Eds.), *Handbook of research methods in personality psychology* (pp. 543-556). New York: Guilford Press.
- Murray, H. A. (1938). *Explorations in personality: A clinical and experimental study of fifty men of college age*. New York: Oxford university press.
- Nesselroade, J. R. (1984). Concepts of intraindividual variability and change: Impressions of Cattell's influence on lifespan developmental psychology. *Multivariate Behavioral Research*, 19(2), 269-286.
- Ortony, A., Norman, D. A., & Revelle, W. (2005). Effective functioning: A three level model of affect, motivation, cognition, and behavior. In J. Fellous & M. Arbib (Eds.), *Who needs emotions? The brain meets the machine* (pp. 173-202). New York: Oxford University Press.
- Rafaeli, E., Rogers, G. M., & Revelle, W. (2007). Affective synchrony: Individual differences in mixed emotions. *Personality and Social Psychology Bulletin*, 33(7), 915-932.
- Rasch, G. (1980). *Probabilistic models for some intelligence and attainment tests*. Chicago, IL: The University of Chicago Press.
- Revelle, W. (1993). Individual differences in personality and motivation: 'Non-cognitive' determinants of cognitive performance. In A. Baddeley & L. Weiskrantz (Eds.), *Attention: Selection, awareness, and control: A tribute to Donald Broadbent* (pp. 346-373). New York: Clarendon Press/Oxford University Press.
- Revelle, W., Amaral, P., & Turriff, S. (1976). Introversion-extraversion, time stress, and caffeine: The effect on verbal performance. *Science*, 192, 149-150.
- Revelle, W., Humphreys, M. S., Simon, L., & Gilliland, K. (1980). Interactive effect of personality, time of day, and caffeine - test of the arousal model. *Journal of Experimental Psychology General*, 109(1), 1-31.
- Revelle, W., Wilt, J., & Rosenthal, A. (2009). Personality and cognition: The personality-cognition link. In A. Gruszka, G. Matthews, & B. Szymura (Eds.), *Handbook of individual differences in cognition: Attention, memory and executive control*. Springer.
- Thurstone, L. L. (1947). *Multiple-factor analysis: A development and expansion of the vectors of the mind*. Chicago, IL: The University of Chicago Press.
- Wilt, J., & Revelle, W. (2009). Extraversion and emotional reactivity. In M. Leary & R. H. Hoyle (Eds.), *Handbook of individual differences in social behavior*. New York: Guilford Press.