Reserving a Key Place for Reality: Philosophical Foundations of Theoretical Rotation

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Abstract: *Factor rotation has been a controversial topic in the history of factor analysis, and preference has always been for a solution that is determinant, such as the simple-structure solution approximated by varimax. Stephenson's preference for judgmental rotation, available in Q methodology software packages such as QMethod and PCQ, is little used, due in part to lack of understanding of its philosophical bases in the writings of Egon Brunswik (psychological cues), J.R. Kantor (specificity), Charles S. Peirce (abductory logic), and Michael Polanyi (tacit knowledge). The philosophical justifications for theoretical rotation are summarized, and concrete examples are presented as illustrations designed to encourage acceptance and more widespread usage.*

Introduction

In introducing dependency analysis in Q methodology, Stephenson remarked approvingly of Kantor's approach, that "it reserves a key place for reality" (1953, 38), and this may be taken as a central principle in his preference for centroid factor analysis and the theoretical rotation of factors: They provide a way for reality and not merely statistical considerations to play a role in inquiry. Centroid factor analysis is widely regarded as only an approximation to the more precise and universally preferred principal components method. On this account, it is not to be found in any statistical packages, with the exception of those specifically designed for analyzing Q technique data (Schmolck 2002; Stricklin 2001). Similarly, judgmental rotation of factors, widely employed in the years preceding computers, is now all but a lost art, regarded with suspicion because of the subjectivity and unreliability thought to attend it. After all, how much faith can be placed in factors when the factor analyst is free to rotate them at will, i.e., judgmentally? This would be akin to

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drawing the regression line whimsically and in violation of least squares and other objective criteria.

This attitude about judgment is part and parcel of the more general ideal of scientific decision-making as impersonal, an ideal that H. I. Brown (2000, 194-5) says "does not come close to describing how science actually works." Scientists do not learn formal rules of decision-making so much as they develop skills in making more and more reliable judgments; i.e., they "learn to exercise judgment ... as they master available knowledge and techniques." Whereas such knowledge and techniques are essential for scientific decision-making, they are inadequate for guiding such decisions.

Although Stephenson placed a high value on theoretical rotation, this procedure is rarely used even among those individuals who frequently employ Q methodology and openly espouse its principles. Addams (2000, 129), for example, notes approvingly that "hand [theoretical] rotations can produce different results ... which, it is argued, more accurately reflect the reality of a particular situation;" yet none of the authors in her edited volume uses this procedure. Comrey and Lee stand virtually alone among R methodologists in asserting that "computer methods of rotating factor axes by means of analytic criteria ... cannot replace intelligent judgment by the investigator as to what kind of rotational solution is appropriate" (1992, 113). However, even Comrey and Lee's rotations are based on statistical criteria (e.g., improving positive manifold, moving closer to simple structure, reducing excess variance, etc.) rather than on any theory about the phenomena under examination. Aalto, by way of contrast, states that theoretical rotation enabled him "to pursue hypotheses, hunches and guesses." In theoretically rotating factors in his study, he "made use of my knowledge of the participants and probed the data to see whether some of the Q sorts in which I had a prior interest, actually were related in any theoretically interesting way" (2003a, 86 *footnote 51*; see also Aalto 2003b, 582 *footnote 13*).

Science is generally suspicious of intuition, which often proves erroneous, but the wariness of judgmental rotation is also fueled by an absence of knowledge concerning its philosophical foundations, which are to be found in such corners as Charles S. Peirce's (1958) abductory logic, J.R. Kantor's (1959) interbehaviorism, Egon Brunswik's (1947) psychological cues, and Michael Polanyi's (1962; 1966) tacit knowledge (see Stephenson 1961; 1980; 1982).[1] Intuition we leave to fend for itself. Our more limited intent is to clarify philosophical principles in hopes of showing that there is a coherent rationale for the theoretical rotation of factors, and that under many, and perhaps most, conditions there is probably no other way to proceed if reality itself is to have any role in the outcome.

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[1] The web pages for these thinkers are linked from the Q methodology page at www.qmethod.org.

Exemplification: A Study of French Identity

The emergence of the European Union has necessarily created tension between identification with the nation-state and identification with a higher level authority structure, and this conflict was recently examined in the French context (Robyn 2000a; 2005). The Q sample, drawn from interviews and the literature of French culture, was administered to a diverse set of individuals of all political persuasions and regions, from rural to urban, including French administrators working in the Brussels headquarters of the EU. A segment of the original centroid factor matrix is shown in Table 1, and it is this matrix — or one similar to it (e.g., from a principal components analysis) — that is normally submitted to rotation to reach a more "meaningful" solution (Thompson 1962). The conventional approach is to seek simple structure through application of varimax technique, but Stephenson found it difficult "to accept one kind of geometrical substructure as, in principle, the only basis for inferences" (1953, 41). Stephenson regarded it as unlikely that any one single set of algorithms alone could be expected to achieve the most desirable result irrespective of context any more than a single medicine could be expected to achieve the best result for everyone with a headache.

Table 1. Unrotated Loadings

Participant Nos.	*Original Centroid Factors*			
	A	*B*	*C*	*D*
1	11	30	05	57
2	29	44	10	04
3	53	44	10	23
4	16	18	02	-56
5	44	09	01	-14
6	17	01	00	30
7	08	34	06	-56
8	61	-45	08	-12
9	53	-55	13	09
10	54	17	02	00
11	-26	64	-19	-06
12	-66	57	17	-04
13	-51	73	-25	17
14	61	-61	16	13
15	12	79	34	-18

Decimals to two places omitted.

In the instant case, contextual specifics included the fact that three of the Q sorts were hypothetical responses constructed by the investigator to represent the ideal-typical nationalist (Participant 13), supranationalist (14), and pluralist (15); all these ideological positions, a literature review suggested, were salient in the French national discussion. In addition, Participant 11 was an administrator in the Paris office of the National Front (the nationalistic party of Jean Marie Le Pen) and Participants 8 and 9 were French administrators in the EU headquarters in Brussels. Over and above factual considerations, there were impressions: Participant 1, for instance, was an elderly non-political housewife who was confused by some of the Q sort statements and often made what appeared to be random choices. There were, of course, other impressions and facts of various kinds known about each of the participants, many of whom the investigator spent hours interviewing. Varimax cannot know about such things since it is restricted to the numerical surface of the matrix in Table 1, but these considerations must be allowed to play a role if we are to provide a "key place for reality."

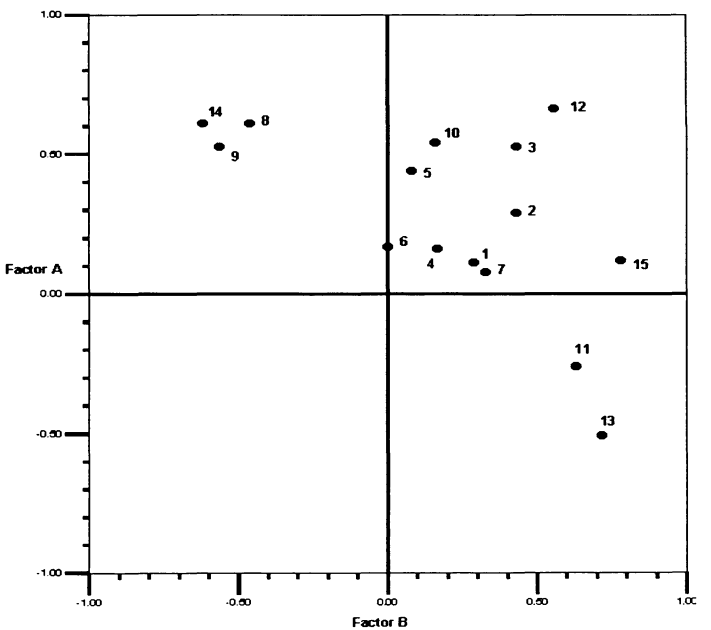

Figure 1. Original Factors A and B

Figure 1 shows the plot of Factors A and B in two-dimensional space, with the locations of the Q sorts being a function of their factor loadings from Table 1. Inasmuch as the purpose of the study revolved around changing conceptions of

French national sentiment, there was particular interest in Participant 11 (of the National Front) since he represented the more extreme form of attachment to symbols of the nation-state, and also in Participants 8 and 9 from EU headquarters. The reference vectors were therefore rotated in such a way as to position these Q sorts near the new vectors, as shown in Figure 2. It is important to note that it was not known in advance that Participants 8 and 9 would be bipolar to Participant 11, although they were of course expected to be different. Once the factors were plotted graphically, however, their relationship became obvious. This was facilitated simply by repositioning the reference vectors so as to bring this relationship into sharper focus.

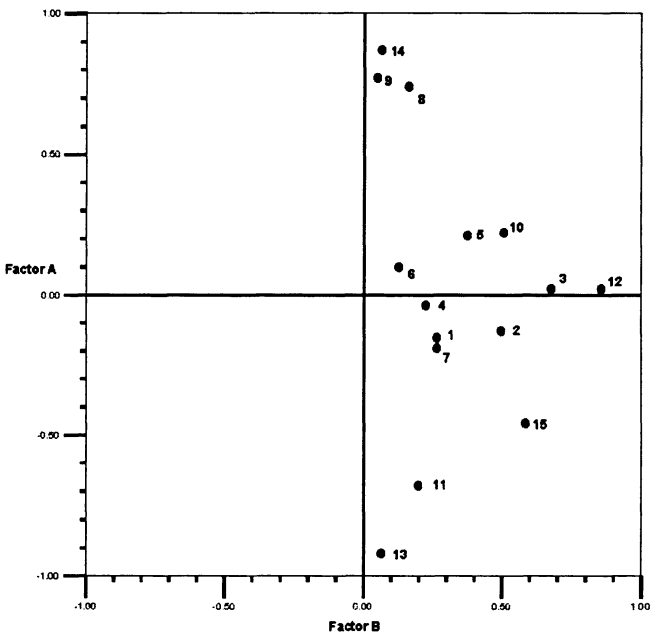

Figure 2. Rotation of Factors A and B

The first rotation changed the loadings of the Q sorts on Factors A and B — e.g., French nationalist Participant 11 changed from -0.26 to -0.68 on Factor A, and 0.64 to 0.21 on Factor B — and the rotated loadings were then examined along with unrotated Factors C and D to determine if a second rotation could improve the emerging structure. The loadings on Factor A were slightly enhanced by plotting them against Factor C, and then rotating them slightly. This served to maximize pro-EU supranationalists at the positive pole of the factor, and nationalists at the negative pole, as shown in Table 2.

With supranationalism and nationalism isolated on Factor A, attention then turned to those Q sorts that remained undefined, and a third rotation paired previously rotated Factors B and C, which were now repositioned so as to focus on a group of individuals whose Q sorts were in the vicinity of theoretical Q sort 15 (traditional pluralism). This rotation was reinforced by interviews indicating that persons clustering around Factor B viewed the EU as an interstate system in which French identity "is a natural part of us as our mountains, rivers and forests," as a mayor of a small village remarked during the post-sorting interview (Robyn 2000b, 320).

Table 2. Final Centroid Solution

Participant Nos.	*Centroid Factors*		
	A	*B*	*C*
1	-15	**47**	**-44**
2	-12	**50**	14
3	02	**73**	02
4	-04	03	**61**
5	20	30	26
6	10	22	-24
7	-19	08	**62**
8	**73**	11	16
9	**77**	08	-06
10	22	**47**	17
11	**-68**	16	13
12	02	**82**	34
13	**-92**	11	-14
14	**87**	12	-10
15	**-46**	**59**	41

Decimals to two places omitted.
Loadings in boldface significant ($p<0.01$).

The supranationalist, nationalist, and pluralist sentiments were anticipated, but once Factors A and B were well defined, it became obvious that there were several Q sorts that did not associate with these factors. Moreover, once these residual Q sorts were highlighted, a working-class demographic began to suggest itself; i.e., the final factor was comprised of a custodian (Participant 4) and a factory worker (7). It is this capacity to discover unanticipated events that is said to be a strength of factor analysis in general (Baird, 1987), and this is especially the case in Q methodology.

The final centroid solution is shown in Table 2, which turned out not to be substantially different from a three-factor principal components solution (with varimax rotation), although the two can differ quite dramatically. (Actually, the principal components solution for all 40 Q sorts indicated that 11 factors had eigenvalues in excess of 1.00, which would have led to an unreasonably complex outcome.) Space precludes going into the detail that would be required to clarify each of the considerations that explicitly affected the rotations. As noted previously, for instance, Participant 1 (an elderly woman with no interest in politics) was confused by the Q sort statements and often made random decisions about where to place some of the items. Foreknowledge of this tendency on her part supported the judgment to ignore her response and focus on those of others. This led to her response playing only a small role in the results, in contrast with her prominent role in defining one of the factors in the principal components solution.

A consequence of factor rotation of any kind, whether judgmental or statistical, is the resultant arrays of factor scores that provide the basis for interpretation. As shown below, the supranationalists comprising Factor A embrace a European identity over that of their nation (Statement *i*); the nationalists at the negative pole of Factor A adopt an opposite view (*ii*); the pluralists of Factor B accept the EU because it would be good for France (*iii*), but do not identify with Europe first (*i*); and the more alienated participants comprising Factor C do not identify with Europe (*i*), nor do they feel especially patriotic toward France (*iv*).

A	*A-*	*B*	*C*	#	*Statement*
+4	-2	-4	-4	(*i*)	I think of myself as a European first, then my own nationality next. I feel I am a citizen of Europe more than of France.
-1	+4	-1	+2	(*ii*)	I want a Europe of nation-states that are as politically and culturally different as they are geographically diverse.
+3	-4	+4	0	(*iii*)	The European Union is a means to ensure peace and stability for France in the future.
+1	-3	-4	+4	(*iv*)	I may obey laws, but I don't feel especially patriotic.

It is to be noted that the patterns of factor scores often hold many surprises over and above surprising patterns in the matrix of factor loadings; i.e., the factor scores frequently reveal ways of thinking that were not anticipated and that constitute discoveries requiring further interpretation and explanation. (For instance, it was expected that Factor A would be wary of the political diversity expressed in Statement *ii* above, due to the supranationalists' concern that political differences not overwhelm the capacity to manage. That the pluralists comprising Factor C would also fail to embrace this statement was counterintuitive and prompted further thinking about this group.) Finally, it is

also to be noted that theoretical rotation can be affected by many different influences. The rotations associated with Factor A, for instance, were in part a response to demographics; i.e., to the fact that the persons at the positive pole of the factor were working in the EU headquarters whereas those at the negative pole were in the Paris office of the nationalist party. However, those rotations were also affected by the originally unanticipated bipolarity that became visually apparent when the data were plotted (Figure 1). By the same token, the Factor C rotations were influenced by comments participants made in interviews rather than by demographics, as well as by Q sorts (such as 15) that had been constructed hypothetically. Factor D was eventually composed of individuals with the same working-class demographic, but unlike Factor A, it was not a social demographic that guided rotation so much as a class of individuals who ended up together almost by default; i.e., as a consequence of various prior rotational decisions. In sum, we often cannot say in advance what stimuli will affect how the rotations will be executed, but in retrospect the rotations that do transpire are tied to the reality of the situation and are never arbitrary.

Philosophical Foundations

Abduction

In 1879, Charles Peirce was traveling by ship to a conference in New York when his expensive watch and other belongings were stolen from his cabin. He assembled the ship's staff on the deck and, after pondering, singled-out the person whom he believed to be the culprit, although, as he confessed, "Not the least scintilla of light have I got to go upon" (cited in Sebeok and Sebeok, 1983, p. 11); i.e., his certainty was high at the same time that supporting evidence was scant. Unable to have the man arrested on such insubstantial grounds, Peirce hired a private investigator to follow the suspect, whose guilt was eventually established.

Peirce used this event to illustrate how guesses — or what he later referred to as abductions — are more often right than wrong. Guessing is preceded by a "passive and receptive state," during which impressions are unselfconsciously absorbed, so that when it becomes necessary to render a judgment even without "the least scintilla of light" and however arbitrary it might seem, that judgment is not capricious, but is guided by the store of impressions. Peirce therefore likened a hypothetic inference to a musical emotion in which a mood results from the combined effect of all the instruments as distinct from the separate sounds of each. Consequently, there is a sensuous element to abduction that is missing in deduction and induction; the former involved with elaborating propositions and the latter testing them. Abduction, on the other hand, seeks for explanations, and its reasoning process is not from general principles to specific consequences (deduction) or from specific observations to generalizations (induction), but from effects to causes.

Earlier, Peirce had conceived of abduction in a narrower sense, as a form of logical inference different from deduction and induction, as seen in Figure 3. Hence, upon entering a room and finding a bag of beans and also a handful of beans on the tabletop, we might reason that the handful of beans had come from the bag. This conclusion is only plausible, however, and could be mistaken. (Hanson [1958], for example, notes that whereas Kepler finally inferred the elliptical orbit of Mars, an ellipsis was not his first guess, because he thought it too obvious. Rather, an ovoid was his first guess, an erroneous hypothesis that he eventually abandoned [see also Ferguson 2002, 316-7].) As a mode of inference, therefore, abduction is initiated by an interesting or puzzling observation (anomaly), such as a non-circular Martian orbit, for which a hypothesis is then abduced in order to provide an explanation. Once a plausible explanation has been entertained, inductive tests can then be carried out. If experimentally borne out, the hypothesis is incorporated into a deductive system that includes the original anomaly as a logical implication. For more detailed considerations of abduction, especially as it relates to induction and deduction, consult Fann (1970), Flach and Kakas (2000), and Magnani (2001).

Deduction ***(possibilities)***	***Induction*** ***(probabilities)***	***Abduction*** ***(plausibilities)***
Rule: all beans in this bag are white	**Case:** these beans came from this bag	**Rule:** all beans in this bag are white
Case: these beans came from this bag	**Result:** these beans are white	**Result:** these beans are white
Result: these beans are white	**Rule:** all beans in this bag are white	**Case:** these beans came from this bag

Figure 3. ***Forms of inference (see Fann 1970, 20 ff).***

The case of Ignaz Philipp Semmelweis (1818-1865)

The history of science is strewn with examples of anomalous observations that have led to the invention of theories and hypotheses. A sterling case in point is that of the Hungarian physician Semmelweis, who discovered the cure for puerperal fever (Slaughter 1950). The main observation requiring explanation in Semmelweis's day was the high rate of death in Vienna's obstetric hospital, and the fact that mortality rates were four times greater in one division of the hospital (15-20% mortality where doctors delivered babies) than in another part (where midwives delivered), a singular fact that was as starkly obvious as it was totally inexplicable. However, this fact enabled Semmelweis to rule out various theories in circulation at the time — e.g., the contagion theory (but why did the contagious disease mysteriously stop at the door of the midwives' sector?) and the atmospheric theory (which failed to account for healthy births by Viennese mothers who, fearing death at the hospital, chose to deliver at home). One by one, Semmelweis ruled out epidemic factors in favor of

endemic ones, and then he began ruling out various endemic explanations — e.g., overcrowding (which was actually a bigger problem in the midwives' clinic) and the role of fear (which failed to account for the large number of deaths before unafraid women became aware that there were problems at the hospital).

Eventually, Semmelweis concluded that the cause had to reside within the doctors' clinic itself, whereupon he began ruling out even more endemic causes, such as the use of forceps, ventilation, and the mixing of dirty linen at the hospital laundry, none of which distinguished the doctors' from the midwives' clinic. New facts began to be noticed — e.g., the greater number of fever deaths among first-pregnancy women whose hospital stay was always longer, the lower mortality among "street births" despite filthier conditions, and the fact that newborns also contracted the disease. And just as Kepler was initially sidetracked by the oviform hypothesis, so did Semmelweis initially abduce wrong explanations. For example, the doctors almost always used the dorsal (on the back) position during childbirth whereas the midwives preferred the lateral (on the side), and so Semmelweis ordered the increasingly resentful doctors to adopt the lateral position for deliveries, but the fever continued to rage in the doctors' division.

Then there came a breakthrough. While Semmelweis was on holiday, one of his medical friends died of a scalpel wound while performing an autopsy, and his symptoms were the same as puerperal fever. In a flash of insight, Semmelweis immediately made the connection between cadaveric material and its transmission via the autopsy knife. (It was Pasteur who later made plain that puerperal fever was transmitted by bacteria, a concept unknown to Semmelweis.) Now it was clear to Semmelweis why there were so many deaths in the clinic run by doctors, who, unlike the midwives, spent mornings in dissection before carrying cadaveric materials on their hands and clothing as they made their rounds in the laying-in clinic. Other puzzling facts were also now explained, e.g., why deaths often occurred in some rows of beds but not others: Doctors attended to mothers in rows, and some attending doctors were not involved in autopsies, hence did not have the deadly material on their hands when they examined their patients.[2] Semmelweis's theory, in short, resulted in *coherence* (Lehrer 1996). His abductory hypothesis having been introduced, Semmelweis then proceeded to test it inductively, first on himself and then by insisting that other attending physicians wash their hands with an antiseptic solution following autopsies. The mortality rate in the doctors' clinic

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[2] Peirce sometimes referred to abduction as *retroduction*, or deduction in retrospect: Had Semmelweis known in advance the way in which disease was transmitted, then deaths in bed rows would have been deduced as a consequence. This is a feature of *genuine* (as opposed to *ad hoc*) hypotheses such as Semmelweis's: Genuine hypotheses explain facts over and above those that they were invented to explain. Just as Newton's theory explained not only falling apples but also the tides, so did Semmelweis's theory permit a variety of previously isolated facts to fall into place.

fell precipitously and reached parity with the rate in the midwives' clinic, and word then spread quickly throughout the medical world. That our mothers insisted that we wash our hands before dinner, and that we have probably had fewer illnesses as a consequence, we owe to Semmelweis.

Stephenson's study of traits

One of the most explicit illustrations of abductory logic within the context of factor analysis is contained in a 1956 paper by Stephenson that is little known among Q methodologists, since it is a study in R methodology. Cattell (1947) had gathered data from students (Xs) who had assessed their peers (Ys) using 36 personality traits (e.g., cheerful, energetic, sociable, etc.). He used R factor analysis to resolve these data into 12 primary factors in simple structure, with each trait having a significant loading on only one of the 12 factors. (Data analysis at this time — prior to the advent of computers and varimax — required a year's labor to rotate the factors to a position in simple structure.) The 12 factors were assumed by Cattell to be the primary dimensions of personality (comparable to primary colors) and to refer to personality structures in the Ys. Stephenson, though, proposed that a *dependency analysis*, combined with an abductory hypothesis, would result in a more satisfactory solution; moreover, that it could be achieved in only a few hours (1953, 30-46).

By way of preparation, Stephenson (1956, 6) first observed that settling on 12 factors runs the risk of over-analyzing the data "into fragments rather than into properly analytic primaries." (With 12 independent primaries, and assuming that persons could be categorized into high and low for each, this would result in $2^{12} = 4096$ distinct personality types!) Second, Cattell's analysis includes no theory about how these primaries are synthesized into secondary traits, in the same way that secondary colors are combinations of primaries. Stephenson provided a metaphor: When arranged in a sidewalk, it is clear which flagstones are primary and which secondary; however, when stacked in piles, the flagstones have the potential for almost any use — to build a house, a sidewalk, or be crushed into sand. As Stephenson concluded, "Cattell's system works only one way, down into primaries, but not up again into complexes."

Stephenson's reanalysis began with Cattell's first six unrotated factors and with the assumption that the trait scores were not properties of the persons assessed (Ys), as Cattell assumed, but were rather "modes of regard" in the persons doing the assessing (Xs), since the source of the operations was in the Xs rather than the Ys. Moreover, he assumed that these modes of regard would be relatively small in number when compared to Cattell's 12 primaries. It was expected, therefore, that for the Xs, traits such as *suspicious* and *jealous* would both be used to express the same mode of regard since these traits would have meaning to the Xs based on their experiences with jealous and

mistrustful types of people. Similarly, Stephenson assumed that trait pairs such as *anxious* and *easily upset* would cohere, as would *alert* and *energetic*, as meanings and stereotypes rooted in experience and in the culture. The factors were therefore plotted, two at a time (as in Figure 1), and rotated theoretically "using these few traits as guideposts," and with these facts "looked at with expectancies of the above kind in mind (a scientific procedure about which I have written elsewhere as an example of the logic of abduction, a method of inference originally outlined by the American philosopher C.S. Peirce and discounted ever since)..." (p. 11). Also entering into consideration was the deduction, based on Stephenson's deep knowledge of Spearman's theory, that the Ys' intelligence, objectively measured, "must tend to be orthogonal to most personality traits;" i.e., intelligence is not expected to be systematically associated with traits such as those in Table 3. As a consequence, "no solution to the rotations will be acceptable which does not have no. 36 [intelligence] distinctly on a factor which is orthogonal to all other factors ..." (p. 11).

Partial results, achieved in just 2 hours according to Stephenson, are displayed in Table 3, and they show six primaries (Factors A to F, the remaining having been discarded following rotation) plus compound traits comprised of those primaries. Thus, only about half of Cattell's primaries were in simple structure, the remainder being mixed.[3] The acid test of the solution is whether the compounds can be explained in terms of the basic factors. The variables defining Factor A led to its characterization as *naughty* (jealous and suspicious, but also demanding), and Factor C's as *immature* (indolent, dependent, socially awkward), which combine to constitute *hypochondriacal* (AC); *obstructive* is comprised of naughty (A) and tough (-D); *unscrupulous* involves a combination of naughty (A), plus vital (B), plus immature (C), plus logical (-E); *boorish* is a composite of immature (C), logical (-E), and unintelligent (-F); and so forth. Stephenson speculated that all the words in *Roget's Thesaurus* could be thus seen as combinations of these six primaries (plus their bipolarities).

In concluding, Stephenson noted that Cattell and other eminent factorists who had previously analyzed this same set of data had always assumed the trait scores to represent factors in the persons rated (Ys) rather than in the raters (Xs), and that his reversal was based not on statistical considerations, but in terms of what was being measured, the source of operations, explanations vs. definitions, and theoretical frameworks rather than analyses

[3] In contrast to "simple structure," which seeks *analytic* power in terms of primary factors, Stephenson's "simplest structure" seeks for *interpretative* power in terms of the smallest number of primaries *plus their combinations* that can explain the data (Stephenson, 1953, p. 41). This has obvious parallels with variance analysis (p. 107), in which main effects A, B, and C also give rise to interactions AB, AC, BC, and ABC. In simple structure, as in Cattell's illustration, the interactions are also represented as separate factors; simplest structure therefore provides the more parsimonious outcome. Note, however, that variance and factor analysis are not simply alternative ways to analyze the data (p. 143).

Table 3. Simplest Structure of Cattell's Primaries

	Selected Traits	*Rerotation of Cattell's Factors*						*Type*
		A	*B*	*C*	*D*	*E*	*F*	
1	obstructive	**51**	25	24	**-38**	-22	-05	A(-D)
2	hypochondriac	**42**	10	**66**	-01	-10	-24	AC
8	easily upset	21	-13	24	**68**	01	-14	D
10	boor	21	-17	**55**	16	**-36**	**-44**	C(-E)(-F)
11	suspicious	**74**	-04	03	11	06	01	A
13	emotional	**33**	**43**	**43**	03	14	-04	ABC
20	indolent	04	19	**81**	-08	06	16	C
22	jealous	**76**	17	06	16	14	17	A
26	anxious	26	-04	21	**47**	-01	00	D
27	unscrupulous	**36**	**31**	**51**	-26	**-41**	07	ABC(-E)
33	expressive	18	**62**	-08	04	13	03	B
34	gregarious	03	**74**	26	07	05	-20	B
35	dependent	15	-20	**68**	26	13	-09	C
36	intelligence	-09	04	01	16	12	**57**	F

Source: Abstracted from Stephenson (1956, 12) and Cattell (1947).
Loadings > ± 0.30 significant and in boldface, decimals omitted.
Intelligence (36) was objectively measured.

leading to atheoretical fragmentation — in short, about methodology broadly conceived. This distinction is of significance, since preference for principal components analysis, varimax, cluster analysis, and other determinant methods rests on statistical considerations, which are conventionally regarded as the only considerations of importance. Given this understanding, Stephenson's use of theoretical rotation appears incomprehensible at best and unscientific at worst[4], but when it comes to science, statistical considerations cannot have the final word. Colombier has said that "the mission of the artist in the electronic age is not to take advantage of technology as a technical power but to bind it to aesthetic decisions" (2003, 257), and at the risk of going from the sublime to the ridiculous, it might also be said that the mission of the scientist is not to take advantage of factor analysis or any similar technology as a technical

[4] An exception is Thompson (1962), who asserted that "the fundamental problem as to whether mathematically exact solutions mirror reality will remain, and judgmental methods will not thereby be outmoded" (p. 211). Thompson surveys the theories of rotation advanced by Cattell, Eysenck, and Burt, but accepts Stephenson's concept of simplest structure as of equal importance (pp. 215-6), concluding that although he (Thompson) accepts simple structure for certain uses, he is "also in sympathy with Stephenson's tendency to emphasize the particular, and takes the view that the technique of rotation to be employed should depend upon the nature of the data, as well as on the aims of the investigator" (p. 222). We would modify this slightly by saying that it is not simply "the aims of the investigator" that drives theoretical rotation, but also the character of reality as understood by the investigator. (Also see text bottom p. 120 and top p. 121.)

technical power, but to bind it to theoretical considerations. In using judgmental rotation rather than varimax, therefore, Stephenson was not naively endeavoring to out-varimax varimax by looking for a statistically more defensible solution, but was providing a key role for reality by taking what was known or suspected as an abductory basis for inquiry, and then engaging the detection capacities of factor analysis and bringing it to heel like a hunting dog in pursuit of answers.

Tacit Knowledge, Cues, and Interactions

The idea that we know something tacitly, or implicitly, is attributed to Polanyi (1962; 1966), whose views have some affinity with Stephenson's (1980). Suppose we suddenly get the impression that someone disapproves of us. We may be unable to say how we know this. Did the person's facial muscles tighten perceptibly? Did the person get slightly flushed? Did the pupils dilate? Did the head turn slightly? Did the eyelids droop? Did the voice become flatter? The evidence may be as scant as we are certain that the person disapproves, just as Peirce was certain that the staff member on the ship had taken his watch.

Although tacit knowledge of this kind is a factor in scientific work, few scientists acknowledge it. Polanyi was, of course, an exception, as was Barbara McClintock, Nobel laureate and geneticist, whose biographer commented about her as follows:

> She herself cannot quite say how she "knows" what she knows. She talks about the limits of verbally explicit reasoning; she stresses the importance of her "feeling for the organism" in terms that sound like those of mysticism. But like all good mystics, she insists on the utmost critical rigor, and, like all good scientists, her understanding emerges from a thorough absorption in, even identification with, her material. (Keller 1983, *xiv*)

Indeed, much everyday behavior is of this tacit kind. We may drive to work as if on automatic pilot, negotiating complicated moves and turns of which we are scarcely aware. Or we type at our keyboard without being specifically aware of striking the K-key or the S-key or any other key. In fact, if we concentrate on the parts of a movement — e.g., become consciously aware of which keyboard keys we are striking, or of the individual fingers as we play a musical instrument — the activity itself slows down and becomes mechanical, and it only resumes its normal rhythm when we forget about it, so to speak. In this regard, Fuchs (2001) speculates that a problem with schizophrenics is that they "disautomate" and become overly conscious about those physical and mental activities that others perform without explicitly thinking about it; i.e., they lose their tacit knowledge.

Brunswik (1947) placed great emphasis on cues and the ways in which they enable us to move about in the external world in the tacit ways that Polanyi described. In controlled experiments, the relationship between cue and

goal is usually unambiguous: If the pigeon presses the red key it gets food; but if it presses the green key, it does not. Brunswik was critical of so-called *systematic* designs of this kind, however, noting that the correlations between cues and targets in the natural world are more uncertain, and that perceptual behavior is, therefore, more probabilistic in character. As is known in Q methodology, for instance, individual statements can take on different meanings depending on the context in which they are embedded, and so background cues are required for orientation. In an early study of human judgment, Hammond (1955) showed how clinicians' assessments of patients' IQs on the basis of Rorschach test results were enhanced when the clinicians were provided with additional cues, such as verbal transcriptions. Posters of wanted criminals show both front and side views, which provides multiple cues and increases the likelihood of recognition. In general, the more cues available, the more likely it is that accurate judgments will be made (for details on Brunswik's work, consult Hammond and Stewart 2001; Leary 1987).

As is well known, Stephenson incorporated much of Brunswik's conceptual framework into Q methodology, especially the idea that the stimulus environment itself had to be sampled (as in Q samples) so as to provide the Q sorter with a variety of cues representative of the stimulus situation. However, he also incorporated Brunswik's conception of cues as applied to factor rotation:

> ... if persons A, B, C, and D can be shown, sociometrically, to be linked to another, E, the investigator may have a "hunch" that factor solutions centered upon E, rather than upon A, B, C, or D, will prove pregnant in some way. There are countless "cues" or "tricks of the trade" of this kind in every science. All are deliberate impositions of inferential and empirical possibilities upon otherwise neutral situations. (1953, 39)

Environmental cues, in turn, depend upon the person's capacity to perceive and interact with them, however tacitly. This is given formal expression in Kantor's (1959, 16) expression for a psychological event — PE = C (k, sf, rf, hi, st, md), where *sf* is the stimulus function, *rf* the response function, *hi* the history of interactions, *st* is the immediate setting, and *md* is the medium (such as light waves) through which *sf* and *rf* are brought into contact; *k* refers to the uniqueness of the factors in a specific setting, and *C* indicates that all factors are in an interacting field. A cat may rub up against someone and begin purring, and the rubbing and purring are stimulus functions to which humans can react; however, the cat's pupils may also be dilating and its heart rate may be elevated, stimulus functions that are undetectable to humans and to which they consequently do not respond. How individuals respond to cats may depend on their histories with cats (*hi*) and on whether a particular cat has just come in out of the rain and is soaking wet (*st*). This specificity of behavior applies as well within science generally, as Stephenson made clear:

> ... the logical analysts and logicians (except for J.R. Kantor) overlook an axiom to which, with Kantor, we attribute greatest importance. It is to the effect that all scientific behavior is *concrete inferential interbehavior*, that is, relatively specific to each experimental situation. This means that there are no absolutist deductive, hypothetico-deductive, or inductive methods or powers at issue. Every experiment, rather, requires its own rules, or some specific to it; and no single set of procedures can fit all the inferential interbehavioral settings of science. (1953, 40)

Table 4. Operant Responses

Ps	*Factors*		
	A	*B*	*C*
1	-04	**69**	-14
2*	**64**	20	-01
3*	**61**	-10	-02
4	**77**	06	-03
5	-36	01	**56**
6	**51**	-10	23
7	17	-01	**74**
8	04	**36**	14
9	13	**50**	21
10*	**53**	03	-11

*females; Significant loadings in boldface.

A simple illustration may suffice (for more details, see S. R. Brown, *in press*). Members of a small undergraduate class read a short feminist story and were asked to respond to it by writing critical essays, from which a Q sample was drawn. (The story was more in the way of a fable in which a king's rejected daughter saves the kingdom by killing the ogre.) The critical essays themselves naturally provided many cues about the students' reactions, but even without the essays, the fact that the story was explicitly feminist and that the unappreciated daughter saved the day would have led to an expectation that female students would respond in a particular way. The original centroid factors were therefore rotated in such a way as to maximize the three female students as defining for a single factor, as shown in Table 4. As is apparent, these rotations did not prevent two males (4 and 6) from also appearing on this factor; nor would these rotations have precluded the possibility of female readers appearing on separate factors. (Theoretical rotation is not alchemy: It cannot create outcomes; it can only assist in the orderly examination of the factor space.) Once the first factor was secure, attention turned to Participant 1 (the investigator) in order to include the observer's

perspective within the field of observation. Two other males (5 and 7) remained residual to the other two factors and were maximized on a third.

Without going into great detail, the feminist character of Factor A was amply recorded in the factor scores:

A	*B*	*C*	#	*Statement*
+4	0	-2	6	It is a classic tale that teaches the lesson that women are on an equal level with men in all aspects.
+4	-1	0	29	The lesson is: Never underestimate the strength and intelligence of a woman.

The author of the story had self-consciously created a feminist story (*sf*) and Factor A readers responded in kind (*rf*). The second factor, however, did not really identify with the explicit theme of the story, but rather enjoyed the story for its own sake:

A	*B*	*C*	#	*Statement*
-1	+4	-4	31	The aspect of the story that I enjoyed most was the non-traditional *denouement* of the female-as-hero.
-2	+3	-2	2	The story has enough old-fashioned excitement and action to make it an excellent yarn.
-4	+2	0	35	A story with a king, a battle, and an evil tormentor makes for enjoyable reading.

It was validating, in retrospect, to recognize that Participant 1, who defined Factor B, was conversant with Stephenson's (1967) play theory and that the factor demonstrated many earmarks of a ludenic response to the story — of enjoyment apart from any message that the story might contain. (Note Factor A's inability to enjoy the story, as shown in Statement 35 above.) The fact that Factor A embodied the feminist response and Factor B the ludenic meant that Factor C had to be orthogonal to both. The statement scores revealed this response to be mainly perplexed, with distinguishing scores going to statements complaining of a lack of information and referring to the story as opaque.

The above results are eminently sensible in retrospect, although at the outset there was little light to guide the way other than a vague expectation, given the character of the story, that women would be apt to respond to it in a particular way unspecifiable in advance. The critic might concede that all worked out for the good in this study, but then wonder whether errors of judgment might not just as well lead us astray in the next study, and there are no guarantees in this regard. That scientists carry prejudices and paradigm fixations of one sort or another into their labs is an old saw that cannot be

denied, but it is also the case that, like cooks in their kitchens, carpenters in their workshops, and all other humans in their natural habitats, scientists enter a data domain armed with considerable knowledge about their subject matter based on readings, past experiments, prolonged and intermittent ponderings, discussions with colleagues, and other experiences. Given this wealth of knowledge, much of it tacit and perhaps incapable of articulation, it seems unprofitable on the face of it to set this advantage aside in favor of the kind of coin toss that varimax and other predetermined solutions provide. Such conventional solutions, of course, guarantee that prejudices play no role at the analytic stage, but they also assure that the scientist's prior knowledge does not apply either; moreover, such prefabricated solutions are subject to erratic vicissitudes and can lead to quite erroneous conclusions.[5] Given the choice between guarding against bias and leaving out knowledge and experience, conventional practitioners of nonjudgmental factor analysis have exercised poor judgment.

In Conclusion: Topography vs. Operantcy

At the first Q conference (1985), the presenter of one of the papers introduced factors that were in simple structure (varimax) and referred to them as *operant* responses, at which point William Stephenson interrupted and asked how the author knew that the factors were operant. The distinction is crucial, since a varimax solution, as with the line of best fit in regression, is wholly at the mercy of the surface features of the data themselves, i.e., of their *topography*. The location of a regression line, for instance, is simply its final resting place once the pushes and pulls of the various data points have cancelled out: Add another data point and the line shifts (however imperceptibly), just as the arithmetic average shifts with the addition of each new observation. The location of the regression line is easier to defend, since it is dependent upon the sample of cases, which are typically chosen randomly, hence should display some stability under future samplings. The location of reference vectors in R factor analysis, however, is dependent to a large extent upon the variables (or persons in Q factor analysis), thus their location is highly affected by the variables included, and these are never chosen randomly.

Imagine what the laws of nature might look like were physicists to reach decisions in the same way that social scientists do. The "law" of gravity would be only an approximate value, a tendency statement based upon averages taken from random samples of falling objects — baseballs, leaves, shoes, etc. Reliability and validity would suddenly become pertinent, as each new sample would produce a new statistical outcome from which to estimate the

[5] In one demonstration (S.R. Brown 1996), the addition of only two Q sorts to a data matrix containing 28 others produced major alterations in the outcome, the most extreme involving two Q sorts that purely defined a common factor in the 28-sort solution, but that defined separate factors in the 30-sort solution.

population parameter assumed to lie beneath the topography. But Galileo sought for a deeper invariance beyond mere surface impressions, and for observations under specialized rather than common conditions; e.g., in a vacuum, where air resistance can be neutralized, enabling feathers to fall as fast as cannon balls.

A theoretical rotation is naturally sensitive to surface features of the data inasmuch as these are among the stimulus functions with which the analyst interacts, but the analyst is not restricted to surface impressions anymore than a parent has to believe that there is nothing bothering a child simply because the child says so. There is, as noted, a sensuous feature to abductory as well as to tacit knowledge: We often know when something does not feel quite right, for instance, or have a vague inclination to pursue one course of action rather than another. We may be unable to articulate the reasons for these sensations — such is the nature of "hunches" (Platt 1931) in science as in other endeavors — but according to Peirce, Polanyi, Brunswik, and Kantor among others, they are not accidental; rather, they are the result of concrete experiences and lessons that have been stored up in the course of our interactions with reality and that provide useful if fallible guides to future interactions. The judgmental rotation of factors is simply a special case of this more general principle and provides a disciplined way for reality as currently understood to play a role in the final solution.

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