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The structure of schizophrenic symptoms: a meta-analytic confirmatory factor analysis[1]

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Abstract

To quantitatively review all presently available evidence about the interrelations between positive and negative schizophrenic symptoms, we created an aggregate matrix of the intercorrelations among schizophrenic symptoms by combining data from 28 independent samples using meta-analytic procedures (net bivariate *dfs* ranging from 683 to 1657). Using confirmatory factor analyses, we then statistically compared four theoretically derived models of the structure of schizophrenic symptoms. Although a three-factor model (Liddle, 1987) best fit the data, results suggest that either more factors or different symptoms are required to account well for the latent structure underlying schizophrenic symptomatology. The nature of such augmented approaches, the opportunities and constraints inherent to multifactorial models, and the limitations of current instruments are discussed.

Keywords: Positive symptoms; Negative symptoms; Factor analysis

1. Introduction

Positive and negative schizophrenia are distinguishable from each other in an impressively wide variety of ways, including their differing ages of onset, response to neuroleptic medication, neuropsychological correlates, and functional versus structural brain abnormalities (e.g., Harvey and Walker, 1987; Lewine, 1985; McGlashan and Fenton, 1992). A network of interrelations with external correlates establishes one component of nosological validity. Beyond this 'external' validity evidence, the model's 'substantive' component is the theoretical basis upon which symptoms are included (and excluded), while its 'structural' component concerns the extent to which relations among symptoms mirror those believed to obtain between source processes underlying symptomatology. The three validity components: (a) external, (b) substantive, and (c) structural, exhaust the necessary and sufficient conditions to claim a diagnostic distinction's validity (Loevinger, 1957). Insofar as the positive/negative distinction is concerned, external validity is well established. Substantive validity is still nascent. The present paper addresses structural validity.

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Structural validity (or 'fidelity') of competing models can be directly tested using confirmatory factor analysis. Prototypic in this regard are the studies by Lenzenweger and colleagues (Lenzenweger et al., 1989, 1991; Lenzenweger and Dworkin, 1996) of positive and negative symptoms and the studies by Harvey and his associates (Harvey et al., 1992; Keefe et al., 1992) and Sayers et al. (1996) of thought disorder and negative symptoms. Using confirmatory factor analysis, these researchers posed highly sophisticated questions of the intercorrelations among schizophrenic symptoms, the answers to which were directly germane to current controversies in the respective literatures.

In addition to these confirmatory factor analyses, the literature also contains a large number of exploratory studies of the structure of schizophrenic symptoms. Much of this activity began with Andreasen and Olsen's seminal unrotated principal components analysis of diagnostic criteria they proposed for positive, negative and mixed varieties of DSM-III schizophrenia (Andreasen and Olsen, 1982). As is frequently done in order to sharpen intercategory distinctions, Andreasen and Olsen (1982) appended exclusion rules to the diagnostic criteria for positive and negative schizophrenia; positive schizophrenia precluded the presence of any significant negative symptoms and negative schizophrenia precluded the presence of any significant positive symptoms. As a result, Andreasen and Olsen's (1982) principal components analysis revealed a pronounced bipolar unrotated first factor, supporting their proposal that positive and negative symptoms are mutually exclusive opposing ends of a single bipolar continuum. That is, the structural validity of the model was tested following the substantive assertion that positive and negative schizophrenia were mutually exclusive. It would be difficult to overestimate the impact of this 'Citation Classic', which had been cited over 480 times by 1993 (Citation Classics, 1993).

If the Andreasen and Olsen (1982) exclusionary rules separating positive and negative symptoms are relaxed, however, bipolarity becomes the exception rather than the rule (e.g., Arndt et al., 1991; Bilder et al., 1985; Green and Walker, 1985; Johnstone et al., 1981; Kay et al., 1986, 1988; Lewine et al., 1983; Liddle, 1987; Lindenmayer et al., 1986; Losonczy et al., 1986; Pogue-Geile and Harrow, 1984; Rosen et al., 1984). In studies such as these, the correlations between positive and negative symptoms tend to be non-significant, while the correlations within these two categories are positive and relatively strong (especially for the negative symptoms). Finally, even with definitional constraints in place, *rotated* factor analyses of the original Andreasen and Olsen (1982) data separate positive and negative symptoms from each other (Andreasen et al., 1995).

In contrast with two-dimensional models of schizophrenia are several three-dimensional models that have also recently gained popularity. Liddle (1987) described a third 'disorganization' factor that separates inappropriate affect, poverty of content of speech and disturbances of the form of thought from 'reality distortion' (delusions and hallucinations) and 'psychomotor poverty' (poverty of speech, lack of spontaneous movement, blunted affect). Similarly, Bilder et al. (1985) found a third factor comprising thought disorder, alogia, bizarre behavior and attentional impairment, that was independent of the positive and negative factors. Kulhara and Chandiramani (1990) found a separate factor that included bizarre behavior and thought disorder. Lenzenweger et al. (1991) found evidence to support the third factor of Strauss et al. (1974): disordered premorbid personal–social adjustment. Brown and White (1992) found inattentiveness and inappropriate affect to separate from positive and negative symptoms in a principal components analysis. In addition to establishing the independence of positive and negative symptoms through a rotated factor solution as described above, Arndt et al. (1991) also found positive thought disorder and bizarre behavior to be distinguishable from positive and negative symptoms. Other three-factor models have been proposed (e.g., Gur et al., 1991), as have four-factor models (Lenzenweger and Dworkin, 1996; Peralta et al., 1992) and a five-factor model (Lindenmayer et al., 1995).

In this investigation we sought to provide a quantitative review of presently available evidence about the structural validity of various positive/

negative models. We believed that even though various idiosyncratic caveats might attach to studies of the schizophrenic symptom structure that have been published since Andreasen and Olsen's (1982) article—caveats that might undermine their individual impact–by aggregating across studies these idiosyncrasies would, to a large degree, be offsetting and a more compelling picture might emerge.

2. Method

2.1. *Identification of articles*

Data for the present investigation were collected from research reports containing intercorrelations between two or more of the classic schizophrenic symptoms derived from ratings of schizophrenic subjects. We began by scanning highly inclusive computerized searches of the published literature in psychology and psychiatry for articles concerned with schizophrenia and its characteristic symptoms. These general searches were augmented with more specific searches keyed on schizophrenia and (a) instruments (e.g., SANS, SAPS, CASH, BPRS, PANNS), (b) researchers (e.g., Andreasen, Harvey, Kay, Lenzenweger, Liddle, Peralta) and (c) procedures (e.g., factor analysis, cluster analysis). All of these searches were restricted to publications since 1980 in order to increase the likelihood that modern diagnostic criteria were applied to the subjects. Next, we hand searched every issue published between 1989 and 1994 of the following five journals: Archives of General Psychiatry, British Journal of Psychiatry, Journal of Abnormal Psychology, Schizophrenia Bulletin, and Schizophrenia Research. In hand searching these journals, we sought any article reporting, even incidentally, the correlations between schizophrenic symptoms. Finally, the reference sections of appropriate articles emerging from these searches were reviewed for any items missed by the computer or hand searches. When articles clearly suggested the existence of unpublished correlation matrices, we contacted the relevant authors. The authors of one report (Harvey, 1994; Keefe et al., 1992) generously provided data beyond those which appeared in their original report, increasing their original sample size substantially and incorporating positive symptoms into their original negative symptom correlation matrix. Two other groups were kind enough to provide unpublished intercorrelation matrices computed from their original publication samples (Kay and Sevy, 1990; White et al., 1994). Descriptive characteristics of the studies included are provided in Table 1.

2.2. *Construction of the matrix*

2.2.1. *Symptom selection and combination*

In the interest of having as many samples as possible contributing to each of the bivariate aggregate symptom correlations, we began by making a list of published symptoms and combining them into groups that were reasonably interchangeable. Because of their broad representation in the literature, the most influential of these decisions concerned our management of BPRS, SANS and SAPS items. Aligning the BPRS with the SANS and SAPS also posed the most difficulty; so for these reasons we will outline this process in some detail.

The first column of Table 2 lists each symptom as it will be identified for purposes of the present article. The next column lists SANS, SAPS and BPRS indicators of each of these symptoms. The final column shows the primary constituents of each symptom as detailed in various publications concerning the instruments (e.g., Andreasen, 1989; Lukoff et al., 1986; Woerner et al., 1988).

In cases where a symptom is captured by more than one item, correlations with the symptom are recorded as the average of the correlations with each of the constituent items. For instance, to determine the correlation between Hallucinations and Delusions from the intercorrelations among BPRS items, we would average three correlations, namely the correlations of 'Hallucinatory Behavior' with (a) 'Grandiosity', (b)'Suspiciousness' and (c) 'Unusual Thought Content'. This is because there are three indicators of delusions, each of which provides an estimate of the underlying construct of 'delusions'. In all

Table 1
Descriptive information on studies included

Authors, year	Dx System	Sx Scale	*n*	% Sz	% Male	Status	Per cent medicated	Mean age (years)	Length of illness (months)
Addington and Addington, 1991	DSM-III	SANS/SAPS	41	100	66	Inpatient; acute	100	30.9	—
Andreasen and Olsen, 1982	DSM-III	SANS/SAPS	52	100	52	Inpatient	—	30.0	—
Bilder et al., 1985	RDC	SANS/SADS	32	94	50	Inpatient; chronic	97	32.5	150.0
Curson et al., 1992	DSM-III	Other	66	100	85	Inpatient; chronic	—	49.4	328.8
de Leon et al., 1993	DSM-III-R	SANS/SEB	115	100	69	Inpatient; acute	100	35.7	122.4
Docherty et al., 1988	DSM-III	TLC	28	100	54	Inpatient; acute	100	31.4	—
Drake and Cotton, 1986	DSM-III	Other	104	100	55	Inpatient; chronic	—	31.4	88.5
Fenton and McGlashan, 1991	DSM-III	SANS/SAPS	187	100	52	Inpatient; acute/chronic	25	—	—
Goldman et al., 1991	DSM-III-R and RDC	SANS/BPRS	40	100	—	Inpatient; acute	0	30.0	69.6
Guelfi et al., 1989	RDC	BPRS	61	100	100	Inpatient; chronic	0	35.2	136.8
Harvey, 1994	DSM-III-R	SANS/SAPS	248	100	94	Inpatient; chronic	70	39.6	198.0
House et al., 1987	ICD-9	PSE-9	68	100	66	Inpatient/outpatient; acute	—	—	0.5
Katsanis et al., 1992	DSM-III	SCL-90	37	100	—	Inpatient; acute	0	24.0	0.1
Kirkpatrick et al., 1989	DSM-III	SDS	70	100	—	Outpatient; chronic	—	—	—
Kulhara et al., 1989	—	SANS/BPRS	95	100	—	—	—	—	—
Lenzenweger et al., 1989	Other	SANS/other	220	100	—	—	—	—	—
Mueser et al., 1991	DSM-III-R	SANS/QLS	26	100	54	Inpatient; acute	100	31.8	—
Peralta et al., 1992	DSM-III-R	TLC/SANS/SAPS	115	100	69	Inpatient; acute	100	35.7	122.4
Pogue-Geile and Harrow, 1984	RDC	Other	39	100	67	Outpatient; chronic	59	24.4	—
Ring et al., 1991	RDC	SANS	40	100	78	Inpatient; chronic	100	34.0	—
Spohn et al., 1985	RDC	BPRS	84	100	73	Inpatient; chronic	86	32.0	—
Thiemann et al., 1987	RDC	SANS/BPRS	35	94	100	Inpatient/outpatient; chronic	—	—	—
Walker et al., 1988	DSM-III	SANS/SAPS	51	100	76	Inpatient; acute	—	33.5	—
White et al., 1994	DSM-III-R	PANSS	134	100	100	Inpatient; chronic	—	73.0	525.6

Dx = diagnostic; Sx = symptom; Sz = schizophrenic; SDS = Schedule for the Deficit Syndrome; QLS = Quality of Life Scale.

cases, averaging was accomplished using Fisher's r to z' transformations before averaging, then z' to r transforming the resulting aveage into the final datum.

The first symptom, Hallucinations, included SAPS 'Hallucinations' and BPRS 'Hallucinatory Behavior'. For studies not employing either of these two instruments, the analogous symptoms, representing perception in the absence of an external stimulus, including auditory, visual, somatic/tactile and olfactory hallucinations, as well as 'voices commenting' and 'voices conversing', were classified in this category.

The second symptom, Delusions, included SAPS 'Delusions' and BPRS 'Grandiosity', 'Suspiciousness' and 'Unusual Thought Content'. For studies not employing either of these two instruments, the analogous symptom, representing fixed false beliefs such as ideas of reference, persecution, control, grandiosity, sin/guilt, jealousy, as

Table 2
Symptom composition

Symptom	Principle constituent	Exemplary variants
Hallucinations	SAPS Hallucinations	Auditory, visual, somatic/tactile, olfactory, voices commenting/conversing
	BPRS Hallucinatory Behavior	
Delusions	SAPS Delusions	Persecution, reference, control, grandiosity, thought insertion withdrawal/broadcasting, sin/guilt, jealousy
	BPRS Grandiosity	
	BPRS Suspiciousness	
	BPRS Unusual Thought Content	
Formal Thought Disorder	SAPS Positive Formal Thought Disorder	Derailment, tangentiality, incoherence, illogicality, clanging, circumstantiality
	BPRS Conceptual Disorganization	
Bizarre Behavior	SAPS Bizarre Behavior	Clothing/appearance, social/sexual behavior, repetitive/stereotyped behavior
	BPRS Mannerism and Posturing	
Flat Affect	SANS Affective Flattening or Blunting	Unchanging facial expression, lack of gestures, poor eye contact, lack of vocal inflections
	BPRS Emotional Withdrawal	
	BPRS Blunted Affect	
Alogia	SANS Alogia	Poverty of amount/content of speech, blocking, increased response latency, perseveration
Avolition/Apathy	SANS Avolition–Apathy	School/work impersistence, physical anergia, diminished grooming/hygiene
Attentional Impairment	SANS Attention	Social inattentiveness, poor concentration, attentiveness during MSE
Anhedonia	SANS Anhedonia–Asociality	Diminished recreation/sex/intimacy/relationships

well as 'thought broadcasting', 'thought insertion' and 'thought withdrawal', were classified in this category.

Our third symptom, Formal Thought Disorder, included SAPS 'Positive Formal Thought Disorder' and BPRS 'Conceptual Disorganization'. For studies not employing either of these two instruments, analogous symptoms, representing fluent but difficult-to-comprehend features of speech like derailment, tangentiality, circumstantiality, neologisms, 'flight of ideas', etc., were also classified in this category.

The fourth symptom, Bizarre Behavior, was represented by SAPS 'Bizarre Behavior' and BPRS 'Mannerisms and Posturing'. For studies not employing either of these two instruments, the analogous symptom, representing unusual and unnatural behavior and movements such as posturing, stereotyped or repetitive behavior, and unusual or unnatural appearance, clothing, or sexual and social acts were also classified in this category.

The fifth symptom, Flat Affect, was represented by SANS 'Affective Flattening or Blunting' and the combination of BPRS 'Emotional Withdrawal' and 'Blunted Affect'. For studies not employing either of these two instruments, analogous symptoms, representing expressive deficits such as inappropriately unchanging face, voice and gestures, poor eye contact, and general affective non-responsivity, were classified in this category.

Alogia, the sixth symptom, was indexed either by the SANS 'Alogia' or by analogous symptoms representing poverty of speech, poverty of content of speech, or retarded/sluggish speech.

The seventh symptom, Avolition–Apathy, was indexed either by SANS 'Avolition–Apathy' or by other symptoms indicating a lack of drive such as school and work impersistence, physical anergia, or neglect of grooming and hygiene.

The eighth symptom, Attentional Impairment, included SANS 'Attention' and analogous symptoms indicative of inattentiveness, poor concentration, or other cognitive difficulties such as those evinced during a typical mental status examination.

Finally, the ninth symptom, Anhedonia, included SANS 'Anhedonia–Asociality' as well as analogous symptoms indicating social anhedonia, including poor relationships, inability to feel closeness, etc.[2]

2.2.2. *Meta-analytic procedure*

Having identified the appropriate set of research reports and determined how to combine symptoms within studies so that a standard datum could be collected from each, the next issue concerned how best to aggregate these data across studies. Following Hedges and Olkin (1985, chap. 11), we z'-transformed each correlation coefficient, multiplied each z' by its degrees of freedom $(n-3)$, summed these weighted z's across the k studies from which they were collected, divided this sum by the sum of the k dfs, then transformed the quotient back into an r for entry into the final correlation matrix. Thus, the influence of each study on the final matrix was proportional to its sample size. The resulting correlation matrix is presented in Table 3, which also contains aggregate degrees of freedom above its main diagonal.

Although input matrices for confirmatory factor analyses are typically based on covariances, there was not enough descriptive information available in the studies to reconstruct enough covariances to support a meta-analysis. We therefore used correlations as the unit of analysis and deployed a CFA technique with appropriate corrections (RAMONA; Browne and Mels, 1992).[3]

2.3. *Confirmatory factor analysis*

2.3.1. *Model specification*

Our translation of the bipolar, one-dimensional and two-dimensional models into factor analytic structural hypotheses followed Lenzenweger et al. (1989), as shown in Fig. 1. The unidimensional severity–liability hypothesis suggests that all schizophrenic symptoms are associated with a single latent factor and their intercorrelations can be accounted for by their joint relations with this single factor. The unidimensional-bipolar hypothesis suggests that all symptoms are related to the same single latent factor, but some of these symp-

[2] The distinctions between some of these symptoms are more difficult to defend than others. There are also some definitional ambiguities that might be masked by these combinations. For instance, although the SANS definition of 'Affective Flattening or Blunting' clearly combines both BPRS 'Emotional Withdrawal' and 'Blunted Affect', 'Emotional Withdrawal' is also evident in the definitions of SANS 'Anhedonia–Asociality' and even 'Attention'. Similarly, although classified for the present investigation as an indicator of Formal Thought Disorder, it has been argued that BPRS 'Conceptual Disorganization' should not include circumstantiality or pressured speech, even if marked (Woerner et al., 1988). Finally, it might be argued that 'Poverty of content' should not be combined with 'Poverty of Speech', given their tendency not to correlate with each other. A couple of points are relevant in this regard. First of all, we believe that some of the subtlety evident in the formal instructions for these scales is likely to be lost during their application. The between-study differences in their application might even, on occasion, exceed these instructional differences. Secondly, we wanted to avoid groupings based on various empirical findings, because we would then be unable to conduct quantitative tests of various theoretical groupings. In any event, one strength of the present meta-analytic approach is the potential for instrument- and the study-specific idiosyncrasies to cancel out upon aggregation. While the consistent application of idiosyncratic symptom definitions might seriously influence the results of a single study or series of studies applying the same instrument, we hoped that by aggregating across studies, and especially across instruments, we could minimize such effects, providing a clearer picture of the correlational structure of schizophrenic symptoms.

[3] By 'correlation', we include phi, tau, Pearson, Spearman, polychoric and any other coefficients of association based on Pearson's as they were reported in the original studies. This variety of reported statistics results presumably from the properties of the data analyzed in each study. Most important in this regard is the fact that some studies used binary (viz. 'present' versus 'absent') ratings, others used the nine-point BPRS scales, and still others used the six-point SANS/SAPS scales. It might be argued that these rating scale characteristics could alter or bias the possible range of the coefficient reported—and, hence, our findings. In fact, when the proper coefficient is computed, the use of a particular kind of scale does not necessarily alter the range of the correlation. The possible range is, however, importantly influenced by the shape of the marginal distributions (Carroll, 1961), and binary ratings and their associated phi coefficients are sometimes thought to be particularly sensitive to this phenomenon. This is a problem in the present investigation to the extent that it is a problem for the previously published studies, and we are forced to assume that the original investigators were mindful of the distributions of their variables and chose the correct models with which to compute their indices of association.

Table 3
Aggregate correlation matrix

Symptom	1	2	3	4	5	6	7	8	9
1. Hallucinations		1373	1552	1249	1537	837	1228	1343	683
2. Delusions	0.34		1493	1315	1478	903	1228	1343	749
3. Formal Thought Disorder	0.24	0.19		1369	1657	931	1343	1343	864
4. Bizarre Behavior	0.24	0.11	0.25		1315	824	1188	1303	709
5. Flat Affect	0.08	−0.05	0.12	0.20		1223	1587	1632	1108
6. Alogia	0.03	−0.17	0.09	0.19	0.56		1157	1087	1223
7. Avolition/Apathy	0.14	0.03	0.11	0.26	0.51	0.46		1736	1146
8. Attentional Impairment	0.16	0.00	0.33	0.22	0.31	0.43	0.33		1191
9. Anhedonia	0.06	−0.03	0.04	0.15	0.46	0.47	0.58	0.30	

Correlations are listed below the main diagonal, pairwise aggregate degrees of freedom appear above the main diagonal.

Table 4
Confirmatory factor analysis model fit statistics

Model	RMSEA	90% RMSEA CI		ECVI	90% ECVI CI		GFI	NNFI
		Lower	Upper		Lower	Upper		
Meta-analytical data set								
Bipolar	0.16	0.15	0.18	0.80	0.70	0.92	0.84	0.52
Severity/liability	0.14	0.12	0.15	0.59	0.50	0.69	0.88	0.67
Dual process	0.11	0.10	0.12	0.42	0.35	0.50	0.92	0.78
Liddle three-factor	0.10	0.09	0.11	0.33	0.27	0.40	0.94	0.82
Lenzenweger data set								
One-factor	0.11	0.09	0.13	0.76	0.62	0.94	0.87	0.58
Uncorrelated two-factor	0.07	0.05	0.10	0.54	0.44	0.67	0.94	0.81
Correlated two-factor	0.06	0.03	0.08	0.47	0.39	0.59	0.95	0.88

CI = Confidence interval. RMSEA is the Root Mean Square Error of Approximation (Steiger, 1990; Steiger and Lind, 1980); ECVI is the Expected Cross-validation Index (Browne and Cudeck, 1993); GFI is the Goodness of Fit Index (Jöreskog and Sörbom, 1984); and NNFI is the Non-normed Fit Index (Bentler and Bonett, 1980; Tucker and Lewis, 1973).

toms relate in opposite ways to this latent factor. According to the dual-process hypothesis, there are two latent factors, unrelated to each other, each of which gives rise to a characteristic set of manifest symptoms.

In addition to these three models, we also tested the adequacy of Liddle's (1987) three-factor model. the most promising of the three-dimensional models we were in a position to test with the present data (e.g., Peralta et al., 1994). According to Liddle (1987) there are three syndromes underlying the intercorrelations among schizophrenic symptoms: (a) psychomotor poverty (poverty of speech, lack of spontaneous movement, and blunting of affect), (b) disorganization (inappropriate affect, poverty of content of speech, and formal thought disorder), and (c) reality distortion (delusions and hallucinations). This system is silent with respect to anhedonia–asociality and bizarre behavior. Since models cannot be compared unless they comprise the same symptoms, we elected to place anhedonia–asociality on the psychomotor poverty factor and bizarre behavior on the disorganized factor, resulting in the three-factor model presented in Fig. 2.

2.3.2. *Goodness of fit indices*

Lenzenweger et al. (1989) and Peralta et al. (1994) report the χ^2 test of exact fit, the Goodness of Fit Index (GFI; Jöreskog and Sörbom, 1984),

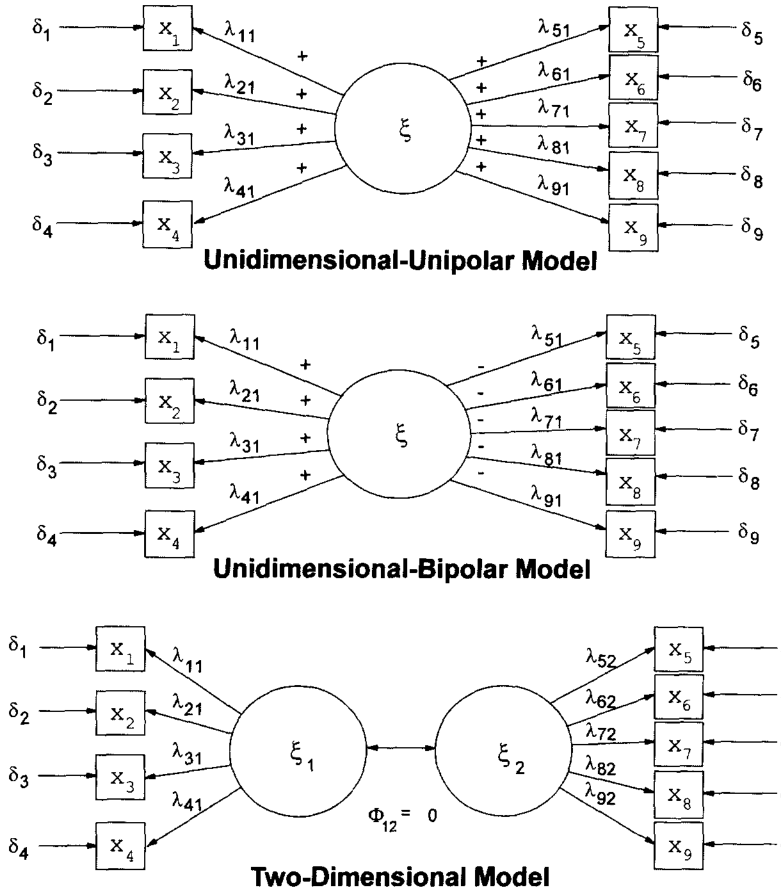

Fig. 1. Models of the latent structure underlying the intercorrelations among schizophrenic symptoms. (Adapted from M.F. Lenzenweger, R.H. Dworkin and E. Wethington, 1989. Models of positive and negative symptoms in schizophrenia: an empirical evaluation of latent structures. J. Abnorm. Psychol. 98, 66.) Catatonic motor behavior was not available in the present study, so compared to the figure of Lenzenweger et al. (1989) some of our observed symptoms have different numbers: x_1 = hallucinations; x_2 = delusions; x_3 = formal thought disorder; x_4 = bizarre behavior; x_5 = flat affect; x_6 = alogia; x_7 = avolition/apathy; x_8 = attentional impairment; and x_9 = anhedonia. In all other respects, this figure is the same. Lambdas (λ) indicate factor loadings, deltas (δ) indicate error terms, xis (ξ) indicate latent factors, and phi (Φ) indicates association between latent factors ξ_1 and ξ_2. Positive and negative factor loadings are indicated with plus and minus signs.

the Non-normed Fit Index (NNFI; Bentler and Bonett, 1980; Tucker and Lewis, 1973), and the Normed Fit Index (NFI; Bentler and Bonett, 1980). Out of a concern for certain limitations of these statistics, we also report Steiger's (Steiger, 1990; Steiger and Lind, 1980) Root Mean Square Error of Approximation (RMSEA), which is a measure of how well the model fits the data in the population, given the number of (free) parameters it has. Somewhat akin to the χ^2 to degrees of freedom ratio, it is the quality of the fit per degree of freedom (Browne and Cudeck, 1993). We also report the Expected Cross-Validation Index (ECVI; Browne and Cudeck, 1993), which estimates how well each model's observed solution would fit in the population. Browne and Cudeck (1993) suggest that values of RMSEA less than 0.05 are required to claim a close fit, with values around 0.08 interpretable as 'mediocre'. RMSEA values greater than 0.10 are generally viewed as indicative of a poor fit. The two net fit indices

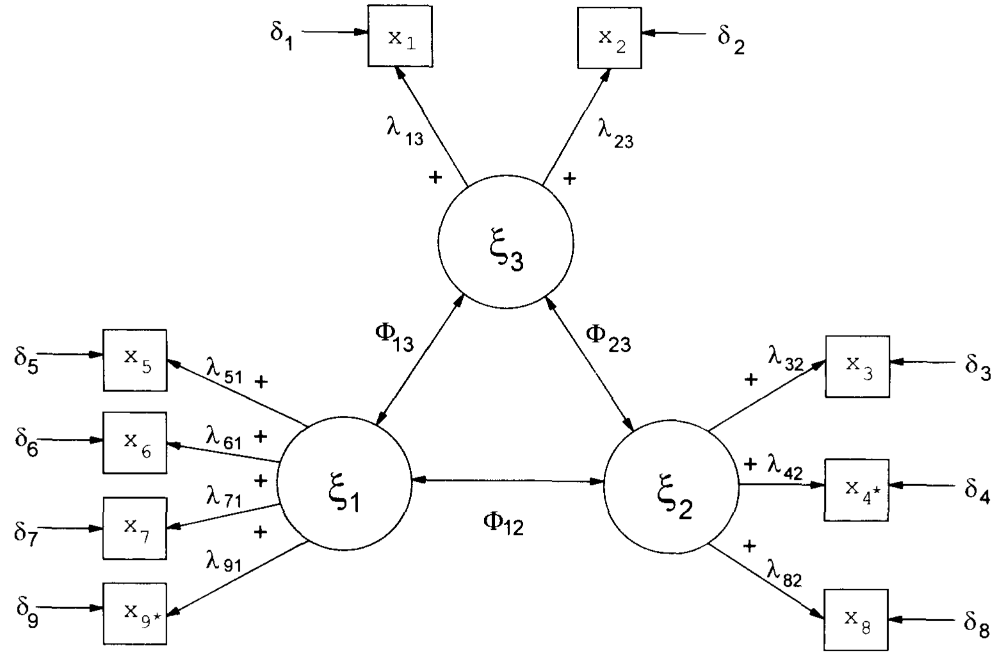

Fig. 2. Three-factor model based partly on Liddle (1987). We augmented the Liddle (1987) model by placing anhedonia/asociality on his Psychomotor Poverty factor, ξ_1, and bizarre behavior, x_4 on his Disorganization factor, ξ_2. These symptoms are marked with asterisks. ξ_1 = Psychomotor Poverty factor, ξ_2 = Disorganization factor, ξ_3 = Reality Distortion factor. x_1 = hallucinations; x_2 = delusions; x_3 = formal thought disorder; x_4 = bizarre behavior; x_5 = flat affect; x_6 = alogia; x_7 = avolition/apathy; x_8 = attentional impairment; and x_9 = anhedonia. Deltas (δ) indicate error terms, xis (ξ) indicate latent factors, and phis (Φ) indicate association between latent factors, ξ_1, ξ_2 and ξ_3. All factor loadings are positive.

were also computed on the Lenzenweger data set and are presented in the Results section for comparison purposes and as an aid to interpretation.[4]

[4] An additional consideration due to the meta-analytic nature of the present investigation is that factor analytic theory assumes that the matrix of correlations to be analyzed comes from a single sample. Thus, strictly speaking, it is not applicable to a matrix developed via meta-analytic techniques. This is somewhat similar to the problem of pairwise deletion of missing cases in a correlation matrix. It is possible for the matrix to exhibit contradictory relationships, or more technically, to result in a matrix that is not gramian. However, the purpose of meta-analysis is to give the best estimate of a result had one study been done on a single large sample. This is the spirit in which we are analyzing the meta-analytically produced correlation matrix: as our best estimate of a correlation matrix had all of the researchers pooled their data. Also, whether or not a correlation matrix is gramian is an empirical matter, and the resulting matrix was, in fact, gramian. Finally, the RAMONA approach allows for the analysis of correlation rather than covariance matrices.

2.3.3. Net sample size

Another issue raised by the meta-analytic nature of this investigation concerns overall sample size. While sample size does not affect the sample discrepancy value, it does affect the estimate of the RMSEA, the ECVI, and all confidence intervals. Because we are not aware of a determinate solution to this problem, we adopted the conservative tactic of choosing the smallest value from among all of the pairwise degrees of freedom in the matrix (viz., $df_{(\text{Hallucinations, Anhedonia})} = 683$; see Table 3).[5]

3. Results

Goodness-of-fit measures from the confirmatory factor analyses are shown in Table 4. Among all of the fits computed on the present data (the RMSEA, ECVI, GFI and NNFI), Liddle's three-dimensional model was best, the two- and one-dimensional severity models fit the data less well, and the bipolar model fit the data least well. In terms of model fit in the population, the RMSEA reveals that the three-factor model is most adequate, and two- and one-factor models less adequate, and the bipolar model the least adequate. In terms of how well the solution obtained in our particular sample is likely to fit the data in the population, the ECVI reveals again that the three-factor model performs best, and the two- and one-factor models perform less well, and the bipolar model performs least well.

Table 4 provides, in addition to the fit indices based on our meta-analytic data, (a) an RMSEA we computed based on the Lenzenweger et al. (1989) data, (b) results of a one-factor confirmatory factor analysis with no inequality constraints, and (c) a two-factor confirmatory factor analysis with no inequality constraints in which we allowed the two factors to correlate (Lenzenweger et al. 1989 did not invoke inequality constraints). For the Lenzenweger et al. (1989) data, the estimate of model fit in the population for the one-factor model was mediocre to poor (RMSEA 90% CI from 0.09 to 0.13). For our meta-analytic data, this fit was even worse (RMSEA 90% CI from 0.12 to 0.15). For the Lenzenweger et al. (1989) data, the estimate of model fit in the population for the two-factor model was good to mediocre (RMSEA 90% CI from 0.03 to 0.08). For our meta-analytic data, this fit was mediocre at best, but more probably poor (RMSEA 90% CI from 0.10 to 0.12). In sum, the three comparable models we tested did not fit our meta-analytic data as well as they fit the data reported by Lenzenweger et al. (1989). One possible reason for the difference might be that, unlike Lenzenweger et al. (1989), lack of data required us to exclude 'catatonic motor behavior' from among the symptoms studied. Also, when fitting the two-factor model, Lenzenweger et al.'s (1989) two-factor model left the correlation between the latent factors to be a free parameter. In our analyses, we fixed this correlation to zero; that is, we tested a two-factor model with orthogonal factors. Lenzenweger et al. (1989) estimated the correlation between the two factors at 0.42. For the present analyses, allowing the correlation between the two factors to be a free parameter resulted in a between-factor correlation of 0.27. Freeing this parameter must have improved the fit of the two-factor model in the Lenzenweger et al. (1989) study. Finally, the fits of Lenzenweger et al. (1989) may have been superior to ours because their sample was diagnosed with stricter European diagnostic criteria that do not suffer from the positive symptoms bias associated with DSM. Also, all of their patients were unmedicated.

We restricted the values of the loadings in case a local minimum occurred within the inequality constrained parameter space that might result in a goodness-of-fit that was not substantively different from the fit of the same model with no inequality constraint. The loadings from the confirmatory factor analyses are shown in Table 5. For the severity–liability model, restricting loadings to be greater than 0.1 resulted in Delusions loading on the boundary. When left free to vary (labeled 'One-Factor' in Table 5), this loading's 90% confidence interval includes zero. For the bipolar model, all of the positive symptom loadings were estimated to occur on the boundary of the restricted space. Clearly, local minimums did not influence findings in the case of the bipolar model. Restricting the parameter space in an attempt to force a bipolar model did not improve the solution. Instead, it revealed that a bipolar model fits the data very poorly. Restricting the loadings to be greater than 0.1 (viz., 0.2, 0.3 and 0.4) had no substantive effect on the estimates of the loadings for the two-factor models.

[5] Treating each correlation as if it were based on the same number of subjects does not ensure that the reported correlations are, in fact, all equally reliable. However, given that they are all based on large 'samples', the difference between the largest and smallest standard errors in the matrix [1/SQRT(1657) vs 1/SQRT(683)] is less than 0.015. Even with the conservative tactic of generalizing the smallest degrees of freedom value, we felt that there was sufficient power to detect model differences, particularly in light of the fact that this study includes vastly more subjects than similar prior studies that were able to identify such differences.

4. Discussion

As concluded by many of the researchers upon whose work the present investigation is built, our

Table 5
Confirmatory factor analysis loadings

	Two-factor models									
	Correlated		Uncorrelated[a]					Liddle three-factor[b]		
Symptom	I	II	I	II	Severity	Bipolar	One-factor	I	II	III
Hallucinations	0.65	0	0.60	0	0.16	0.10*	0.15	0	0	0.91
Delusions	0.48	0	0.41	0	0.10*	0.10*	0.04[c]	0	0	0.37
Formal Thought Disorder	0.42	0	0.46	0	0.20	0.10*	0.19	0	0.44	0
Bizarre Behavior	0.38	0	0.45	0	0.32	0.10*	0.31	0	0.44	0
Flat Affect	0	0.71	0	0.71	0.71	−0.73	0.71	0.72	0	0
Negative Thought Disorder	0	0.72	0	0.71	0.70	−0.75	0.71	0.71	0	0
Avolition Apathy	0	0.72	0	0.73	0.74	−0.74	0.73	0.73	0	0
Attentional Impairment	0	0.48	0	0.49	0.51	−0.49	0.51	0	0.65	0
Anhedonia Asociality	0	0.70	0	0.69	0.69	−0.72	0.68	0.69	0	0
RMSEA	0.11		0.11		0.14	0.16	0.13	0.10		

[a]The between-factor correlation for the oblique two-process model was 0.11 (CI_{90}=0.03, 0.19).
[b]For the Liddle three-factor model the interfactor correlations were $r_{(I,\ II)}=0.63$, $r=_{(I,\ III)}=0.11$, $r=_{(II,\ III)}=0.40$.
[c]Loading does not differ significantly from zero.
*Indicates loading on the inequality constrained border.

results suggest that the structure of schizophrenic symptoms cannot be reduced to a single bipolar dimension ranging from positive symptoms on one end to negative symptoms on the other, with an attendant negative correlation between them. Nor, however, can the structure of schizophrenic symptoms be accounted for by hypothesizing a single unipolar dimension or two independent dimensions. Even three factors do not capture the structure among schizophrenic symptoms. Either more latent variables underlie the intercorrelations among schizophrenic symptoms, or the set of symptoms most often studied is incomplete.

An important source of ambiguity about the number of latent variables out of which the intercorrelations among schizophrenic symptoms can be derived comes from ambiguity about the manifest indicator variables. Although there appears to be remarkable consensus about what variables are of importance in studying schizophrenia, consensus does not ensure comprehensiveness. It remains possible that important symptoms remain neglected and that the failure to study these symptoms handicaps the ability of important underlying latent constructs to compete for factor status in a manner that would enhance the statistical fits between the hypothesized and observed symptom intercorrelations. Although the point is a general one, an obvious example of it is evident in our inability to identify more than a couple of articles reporting the symptom correlations of premorbid social adjustment (Keefe et al., 1989; Lenzenweger et al., 1991; Strauss et al., 1974). In fact, impressive programs of research have been built around more comprehensive instruments such as the PANSS (Kay, 1991), and more complex models seem to be supported by analyses of these more extensive assessments (Kay and Sevy, 1990; Lindenmayer et al., 1995).

This conceptual point about the *identification* of input variables has a psychometric counterpart related to the *quality* of the input symptoms. In the present investigation, the quality of the input symptoms was constrained by a number of features, including possible differential reliabilities among the variables, the aggregation of symptoms within scales, and the aggregation of scales across instruments. First of all, there are indications in the literature (e.g., Andreasen and Olsen, 1982; Peralta et al., 1992) that positive symptoms are less reliably measured than are negative symptoms. Variables with lower reliability can appear in factor analytic investigations to be separate from those comprising the higher reliability variables. In this regard, it might even be argued that uniformly lower reliabilities would be preferable to differential reliability. A second, although related, point concerns the combination of specific symptoms into more general scales. To the extent that inappropriate combinations are formed, reliability and validity will be reduced. In fact, there are indications in the literature that, particularly in the case of the SANS/SAPS, the constituent variables do not group empirically in the way that the the original rational scheme dictates (Keefe et al., 1992). Clearly, increasing the aggregate sample size, as in the present investigation, does not solve power problems caused by instrument reliability, coding reliability and the degree to which symptoms can truly be 'equated'.

With the present meta-analytic findings and the previous research upon which they are built in hand, it is perhaps fair to comment directly on the issue of the number of factors underlying schizophrenic symptoms. It is clear that unidimensional models, whether unipolar or bipolar, are inadequate. Two- and, where tested, three- (Lenzenweger et al., 1991) factor models perform better. There is also strong evidence that a four-factor model that splits positive symptoms into those encompassing reality distortion and those encompassing disorganization along with negative symptoms and premorbid social adjustment fits best of all (Lenzenweger and Dworkin, 1996).

The superiority of multidimensional models does not, unfortunately, rest on the fact that they are very good in an absolute sense. For instance, the best two-factor model we fit in the present investigation involved applying optimized exploratory factor weights, resulting in a RMSEA of 0.08. The RMSEA we computed from the two-factor model tested by Lenzenweger et al. (1989) was 0.06 and for their three-factor model (Lenzenweger et al., 1991) was 0.10. The best model fit to the meta-analytic data was Liddle's, with its RMSEA of 0.10. In this sense, then, our overall success in accounting for the intercorrelations among schizophrenic symptoms remains, for now, mediocre. Progress toward more adequate models, however, begins with insight into the inadequacy of current ones.

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