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Dimensions of Executive Functioning in Schizophrenia and Their Relationship With Processing Speed

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Context: **The nature of executive dysfunction in schizophrenia is nebulous, due to inconsistencies in conceptualizing and operationalizing the construct, and the broader question of whether schizophrenia is best characterized in terms of specific vs generalized cognitive deficits. The current study aimed to determine whether executive functions represent unitary vs diverse constructs in schizophrenia.** ***Methods:*** **Participants included 145 community-dwelling individuals with schizophrenia. Executive functions were measured with the Delis-Kaplan Executive Functioning System (D-KEFS). We conducted an exploratory factor analysis (EFA) with principal axis factoring, as well as parallel analyses to examine the latent constructs underlying the D-KEFS tasks, a second EFA on weighted residuals of the D-KEFS tasks (after accounting for processing speed measured with the Digit Symbol task), and bivariate correlations to examine relationships between the D-KEFS components and relevant demographic and clinical variables, crystallized verbal knowledge, and functional capacity.** ***Results:*** **EFA of the D-KEFS tasks yielded 2 factors (cognitive flexibility/timed tests and abstraction). EFA of the processing speed-weighted D-KEFS residuals also yielded 2 factors (cognitive flexibility and abstraction). Cognitive flexibility was negatively correlated with psychopathology. Better abstraction was associated with higher education, shorter illness duration, and better functional capacity. Both factors were positively correlated with crystallized verbal knowledge.** ***Conclusions:*** **Executive functions in schizophrenia could be parsed into 2 partially related but separable subconstructs. Future efforts to elucidate functional outcomes as well as neurobiological underpinnings of schizophrenia may be facilitated by attending to the distinction between cognitive flexibility and abstraction.**

Key words: cognitive flexibility/abstraction/D-KEFS/factor analysis

Introduction

Ever since Kraepelin's descriptions of schizophrenia as a dementia praecox a full century ago, there has been suggestion that what are now called the "executive functions" may be of particular relevance to understanding this disorder.[1–3] Investigating such possibilities is warranted because identifying patterns of specific cognitive deficits associated with schizophrenia could help elucidate the dysfunctional brain systems at the core of this condition. Yet, despite innumerable neuropsychological studies of schizophrenia,[4] the identification of specific "core" cognitive deficits has remained elusive.[5,6]

Several factors have impeded definitive determination of the nature of executive dysfunction in schizophrenia. Foremost, the construct of executive functioning is "fuzzy"—there has been a lack of precision and consistency with regard to what cognitive abilities are and are not included under the umbrella term, executive functions. We reviewed published reports on executive functions in general, and specifically in schizophrenia, including early 20th century writings of Vygotsky[7] and Kraepelin,[8] and more contemporary reviews[1,2] and noted that a number of potentially independent cognitive skills have been included under the label executive functions, such as abstract thinking and concept formation, goal formulation and planning, cognitive flexibility, self-monitoring, response inhibition, fluency, and the supervisory attentional system of working memory.[9] Each of these skills or processes is itself multidimensional, and some of the most popular measures of executive functioning may be equally appropriately categorized into nonexecutive cognitive domains. For instance, letter and category fluency may be grouped with expressive language functions or processing speed, as well as executive functioning.[10] The lack of consistency in defining executive functions both as a construct and in terms of operationalization of the construct, as well as the perennial problem of unknown psychometric equivalence among the measures,[11] has considerably limited the ability to make head-to-head comparisons between the subdomains of executive functions within and across studies and to draw firm conclusions about the nature of executive dysfunction in schizophrenia.

Mahurin and colleagues conducted an exploratory factor analytic study of various commonly used executive functioning tests, as well as other tests of frontotemporal function in schizophrenia, and found 3 factors: (*a*) verbal processing/memory, (*b*) cognitive flexibility/attention, and (*c*) psychomotor speed/visual scanning.[12] (Only the second of those 3 describes an ability traditionally subsumed under the domain of executive functions.) There have been several prior published reports of factor analysis of cognitive measures, including executive functioning measures, in schizophrenia, but the standard method has been to use principal components analysis (PCA). PCA is an exploratory method appropriate for data reduction, but it is not appropriate for explorations of structure.[13] Confirmatory factor analysis (CFA), which is also a widely used factor analysis method, is a robust hypothesis-testing approach used to test a theory about latent processes, guided by empirical findings.[14] However, empirical findings have been too inconsistent to support any single model of executive functions in schizophrenia, and using CFA, in the absence of a strongly established model from which to develop a priori hypotheses, may be problematic. In the absence of a strong theory or model justifying CFA, an appropriate exploratory method is principal axis factoring, which identifies latent structure by partitioning only variance that is shared among indicator variables rather than both shared variance and variance that is unique among indicator variables.

The lack of consistent findings or consensus models is at least partially attributable to the wide discrepancy among studies in the subconstructs selected as comprising executive functions and the tasks used to measure them.[15–17] To clarify the nature of executive dysfunction in schizophrenia, an ideal test battery would have at least 2 characteristics: (*a*) standardized assessment of a broad array of skills commonly grouped under the broader rubric of executive functions, and (*b*) development and conorming of the test battery such that comparison of differential deficits among the component tests/constructs rests on empirically established psychometric equivalence. Although it may not perfectly attain these ideals, the Delis-Kaplan Executive Function System (D-KEFS[18]) represents a reasonable approximation of such a battery. It includes a diverse array of 9 executive subtests (measuring 10 purported executive constructs) and was specifically developed and standardized to permit direct comparison among the different components in teasing out different executive skills, as well as component subskills and basic cognitive functions.

There was one recent study on the association of psychopathological symptoms to executive components measured by the D-KEFS, which also included a factor analysis of the D-KEFS.[19] However, their results are difficult to interpret, not only because they used PCA to analyze latent structure but also because their analyses did not consider the confounding influence of method (timed vs untimed tests) on the overall factor structure.[20,21] Psychomotor/mental processing speed, as indexed with tests like the Digit Symbol subtest of the Wechsler scales, is among the most commonly impaired cognitive functions among persons with schizophrenia.[22] Combined with the fact that approximately half of the D-KEFS tests are time dependent, it is particularly important to consider whether the pattern of associations among D-KEFS subtests reflects method variance (specifically time/processing speed) rather actual than associations among the higher level cognitive constructs. Thus, in the analyses described below, we specifically examined the degree to which the observed factor structure was altered by accounting for processing speed performance.

The aim of the present study was to determine the degree of shared vs independent variance among executive tasks and the overall factor structure of the D-KEFS. We first examined the dimensionality of the 10 D-KEFS executive functioning tasks in our sample of people with schizophrenia. Given the lack of an established compelling model of executive functions in schizophrenia and inconsistent factor compositions of executive functions in prior studies, we chose not to preconstrain the number and types of factors. Instead, we used exploratory factor analysis (EFA; principal axis factoring) and parallel analysis to determine the factor structure of the D-KEFS. We also examined the degree to which the latent constructs yielded by the EFA would hold after accounting for processing speed, ie, to determine the degree to which the D-KEFS factor structure might be affected by the distinction among timed vs untimed subtests. In addition, we examined whether specific executive functioning subconstructs might be differentially associated with potentially relevant indices of heterogeneity in schizophrenia, such as crystallized verbal skill (as a proxy for premorbid cognitive functioning), demographic variables, severity of psychopathology, and functional capacity.

Methods

Participants

Participants were 145 community-dwelling individuals with schizophrenia or schizoaffective disorder. (These participants contributed D-KEFS data to a prior report[23]; however, the focus of that study was on determining the presence of differential deficits among patients relative to normal comparison (NC) subjects. NC subjects were not included in the present report; there are notable concerns about the construct validity of factor analyses for cognitive data from NC subjects when applied to neuropsychiatric populations.[24]) The data for 124 of these participants were originally collected as part of 2 ongoing studies at the University of California, San Diego (UCSD) led by one of the coauthors (E.W.T.). The remaining 21 subjects were recruited and assessed to specifically study executive functions in schizophrenia. Diagnoses for the 21 participants whose data were collected prospectively were established with the Mini-International Neuropsychiatric Interview (MINI). Diagnoses for the other 124 participants were established by their treating clinicians and then confirmed via chart reviews by formally trained research associates and postdoctoral fellows using a checklist of *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* (DSM-IV) criteria. All participants were outpatients receiving treatment at the UCSD Outpatient Psychiatry Services. Participants with schizophrenia or schizoaffective disorder were included if they were at least 18 years old at the time of enrollment and had the ability to give written informed consent to participate. Potential participants were excluded if they had a concurrent DSM-IV diagnosis of dementia or delirium at the time of enrollment, a history of head injury or loss of consciousness for 30 minutes or more, or substance abuse or dependence per DSM-IV-TR within 1 month prior to enrollment. The current and parent studies were approved by the UCSD Human Research Protections Program, and all participants gave written informed consent to participate.

Schizophrenia and schizoaffective disorder were combined in our sample as the existing literature suggests that the two groups are generally indistinguishable in terms of neurocognitive functioning.[25] This was supported by our data that showed no differences in terms of demographics, clinical symptoms, or crystallized verbal knowledge between the two subgroups.

Assessments

Demographic information and information related to disease burden (such as age of onset of psychosis and type of antipsychotic medications) were collected for each participant via self-report and, with participant authorization, review of available records. Presence and severity of psychopathology and depression were assessed with the Positive and Negative Syndrome Scale (PANSS) and the 17-item Hamilton Depression Rating Scale (HAM-D). We used the positive and negative symptom scores from the PANSS and the total score on the 17-item HAM-D in correlational analyses with the D-KEFS factors.

Executive functions were assessed as part of a larger neurocognitive test battery, with ten tasks from the nine tests of the D-KEFS[18]: Trail Making (Number-Letter Switching, time to completion), Verbal Fluency (Category Switching, total correct), Design Fluency (Switching, total correct), Color-Word Interference (Inhibition and Inhibition/Switching, time to completion), Sorting (Free Sorting Confirmed Correct sorts), Twenty Questions (total achievement score), Word Context (total consecutively correct), Tower (total achievement score), and Proverb test (Free Inquiry, total achievement score). Normalized scores (z-scores) were used as the observed variables for the factor analysis.

We estimated premorbid verbal IQ with the American National Adult Reading Test (ANART).[26] Processing speed was measured with the Digit Symbol subtest of the Wechsler Adult Intelligence Scale—Third Edition.[27] Normalized scores (z-scores) were used in regression analyses used to obtain weighted residuals of the D-KEFS scores (please see details of method used in "Statistical Analyses" section below).

Everyday functioning capacity was examined with the UCSD Performance-Based Skills Assessment (UPSA), comprising role-play measures of finance, communication, recreation planning, transportation planning, and household chore skills. The total score was used in correlational analyses with the D-KEFS components.

Statistical Analyses

An EFA with principal axis factoring and direct oblimin rotation was conducted to explore the latent constructs underlying the 10 D-KEFS executive functioning tasks (See online supplementary table 1 for correlations among tasks). Analyses were conducted in Predictive Analysis SoftWare (PASW/SPSS version 18.0). The variance accounted for by the solution, the variance accounted for by each individual component, and the interpretability of the factors were evaluated to determine the initial plausibility of the factor structure. We determined a priori that primary pattern coefficients of >0.30 would reflect the selective loading of a task on any given factor. Parallel analysis using Monte Carlo simulation methods was used to further support the factor structure.[13]

In order to parse out the variance explained by processing speed, we then conducted a second EFA with direct oblimin rotation, along with parallel analysis on the studentized residuals of each of the 10 D-KEFS tasks after accounting for scores on the Digit Symbol test. We obtained the residuals by means of linear regression analyses wherein each of the 10 tasks was the dependent variable, and the normalized score of the Digit Symbol task was the independent variable. We examined the relationships of the executive functioning factors yielded by the second EFA with relevant demographic and variables, crystallized verbal knowledge, as well as functional ability (UPSA total score) via Pearson's bivariate correlations.

Table 1. Exploratory Factor Analysis of D-KEFS Executive Functioning Tasks: Primary and Secondary Loadings

	Cognitive Flexibility/Timed Tasks (Variance Explained = 31.2%)	Abstraction (Variance Explained = 7.7%)
Color-Word Inhibition/Switching	**0.90**	−0.16
Color-Word Inhibition	**0.81**	0.00
Design Fluency Switching	**0.64**	0.07
Trails Number-Letter Switching	**0.54**	0.21
Verbal Fluency Switching Correct	**0.39**	0.18
Word Context	0.03	**0.78**
Proverb	−0.06	**0.60**
Sorting	0.14	**0.58**
Twenty Questions	−0.03	**0.52**
Tower	0.14	**0.30**

Note: D-KEFS, Delis-Kaplan Executive Function System. Correlation between 2 factors = 0.57. Loadings reflect pattern coefficients yielded by principal axis factoring. Bold values reflect primary loadings.

Results

Sample Description

Participants, on average, were 48.5 years old (SD = 8.6) and 63.4% were men. The mean education level of the sample was 12.7 years (SD = 2.3); 54.5% of the participants self-identified as Caucasian, 26.2% as African American, and 12.4% as Latino; 76.4% were living independently, either alone or with someone, 46.5% were single (never married), and 11.1% were either married or were living with a partner. The participants' estimated premorbid verbal IQ was within the average range (ANART-estimated IQ = 105.9, SD = 9.5).

On average, the participants were clinically stable, with mild levels of psychopathology as suggested by the mean PANSS scores (positive symptoms = 15.8, SD = 5.8; negative symptoms = 14.8, SD = 5.0) and mean HAM-D score (11.9, SD = 6.6). Mean age of onset of psychosis was 23.6 years (SD = 10.03). Eighty-four percent of the participants were prescribed second-generation antipsychotic medications.

The participants' performance on the D-KEFS measures ranged from the low average range (eg, Tower total achievement, mean scaled score = 8.5, SD = 3.9; Sorting Confirmed Correct Sorts, mean scaled score = 8.2, SD = 3.1) to the moderately impaired range (eg, Trails Number-Letter Switching, mean scaled score = 6.6, SD = 3.6; Color-Word Inhibition, mean scaled score = 6.6, SD = 3.8). (Further details on the level of impairment on the D-KEFS tasks are presented in Savla et al.[23])

Dimensionality of D-KEFS Tests

EFA of the 10 D-KEFS scores yielded a two-factor solution as the best fit for the data. The variance explained by the solution was 42.9% and the two factors individually accounted for 35.1% and 7.7%, respectively, of the variance. The parallel analysis supported this two-factor solution as the most interpretable model. The eigenvalues from this PCA were compared with the eigenvalues from the randomly generated components: component 1, 4.03 vs 1.43 and component 2, 1.29 vs 1.28. Although the eigenvalues for the second component are close, we chose to retain it for the following reasons: (*a*) it accounts for more than 7% of the variance in the items, (*b*) the two components share only 32.5% of their variance (r = .57), and (*c*) the factor loadings achieved simple structure.

The 10 pattern coefficients were generally high (absolute value loadings ranged from 0.30 to 0.90) (table 1). None of the factors displayed secondary loadings higher than 0.21. Factor 1 was comprised of 5 items: Color-Word Inhibition (time), Color-Word Inhibition/Switching (time), Trails Number-Letter Switching (time), Design Fluency Switching (total correct), and Verbal Fluency Switching (total correct). Examination of the item content of factor 1 suggests that it may be appropriately conceptualized as a "cognitive flexibility" component, ie, the ability to coordinate attention and response to 2 or more ongoing tasks and to adaptively switch response strategies in accord with contextual demands. Factor 2 was also comprised of 5 items: Proverb (total achievement score), Twenty Questions (total weighted achievement score), Word Context (total consecutively correct), Sorting Task (confirmed correct), and Tower (total achievement score). Examination of the item content of component 2 suggests that it may be appropriately labeled as an "abstraction" component, ie, the ability to discern underlying relationships or associations on a conceptual level rather than at a merely superficial sensory-perceptual level. Notably, the tests comprising the cognitive flexibility factor are all timed, whereas the tests comprising the abstraction factor are mostly untimed (Sorting and Tower being the only timed tests). The 2 factors were positively correlated (r =.57), indicating that in general, individuals with good abstraction/conceptualization abilities are also likely to have good switching/cognitive flexibility skills.

Table 2. Relationships Between D-KEFS Tasks and Processing Speed

	Correlation With Digit Symbol		Variance Accounted for by Digit Symbol			
D-KEFS Task	*R*	*P*	Adjusted R^2	*B*	SE	*P*
Trails Number-Letter Switching	.529	<.001	.275	0.529	0.071	<.001
Verbal Fluency—Category Switching	.452	<.001	.199	0.447	0.074	<.001
Design Fluency—Switching	.506	<.001	.251	0.496	0.071	<.001
Color-Word Interference—Inhibition	.517	<.001	.262	0.517	0.072	<.001
Color-Word Interference—Inhibition/ Switching	.496	<.001	.241	0.496	0.073	<.001
Sorting	.404	<.001	.158	0.398	0.075	<.001
Twenty Questions	.158	.029	.018	0.156	0.081	.057
Word Context	.354	<.001	.119	0.352	0.078	<.001
Tower	.200	.008	.033	0.199	0.081	.016
Proverb	.238	.002	.050	0.238	0.081	.004

Note: D-KEFS, Delis-Kaplan Executive Function System.

Dimensionality of D-KEFS Tests Controlled for Processing Speed

The 10 D-KEFS scores were all significantly related to the processing speed task (all *P*s < .029), with correlations ranging from *r* = .529 (for Trails Switching) to *r* = .158 (for Twenty Questions; see table 2).

The EFA conducted on the 10 D-KEFS residual scores yielded a 3-component solution. The total variance explained was 39.4% and the 3 components individually accounted for 24.6%, 9.8%, and 5.0%, respectively. Two of the three factors were interpretable, but the third was comprised solely of the Tower task. Verbal Fluency did not significantly load on any of the 3 factors. Per factor analysis protocol, we reconducted the EFA without these 2 variables. The new model yielded 2 factors, explaining 38.7% of the total variance. The factors individually explained 27.4% and 11.3% of the variance, respectively, and each had a strong simple structure (see table 3); they could be conceptualized as tasks measuring cognitive flexibility and abstraction, respectively. The parallel analysis supported the two-factor solution as the best fit for the data, with eigenvalues as follows: factor 1, 2.77 vs 1.4 and factor 2, 1.44 vs 1.23 (see online supplementary table 1 for all eigen values). The two factors were positively correlated (*r* = .42).

Relationships of D-KEFS Factors (Controlled for Processing Speed) With Demographic and Clinical Variables, Crystallized Verbal Knowledge, and Functional Capacity

Table 4 presents the correlations between the executive functioning subconstructs (after accounting for processing speed) and other variables of interest. Abstraction had a small but statistically significant positive correlation with years of education and a small but statistically significant negative correlation with duration of illness (longer the duration of illness, worse the abstraction). Cognitive flexibility but not abstraction had a small but statistically significant negative correlation with the PANSS positive symptom and HAM-D depressive symptom scores. Negative symptoms were not

Table 3. Exploratory Factor Analysis of D-KEFS Residual Scores (Accounting for Processing Speed): Primary and Secondary Loadings

	Cognitive Flexibility/Time Tasks (Variance Explained = 27.4%)	Abstraction (Variance Explained = 11.3%)
Color-Word Inhibition/Switching	**0.88**	−0.16
Color-Word Inhibition	**0.67**	0.02
Design Fluency Switching	**0.50**	0.06
Trails Number-Letter Switching	**0.37**	0.19
Word Context	0.01	**0.78**
Proverb	−0.05	**0.58**
Sorting	0.06	**0.54**
Twenty Questions	0.01	**0.47**

Note: D-KEFS, Delis-Kaplan Executive Function System. Correlation between 2 factors = 0.42. Loadings reflect pattern coefficients yielded by principal axis factoring. Bold values reflect primary loadings. Verbal Fluency and Tower were dropped from the final factor analysis because they had no strong univocal loadings.

Table 4. Correlations Between Executive Functioning Components (Processing Speed Accounted for) and Relevant Demographic and Clinical Variables, Crystallized Verbal Knowledge, and Functional Capacity

	Cognitive Flexibility		Abstraction	
	Pearson's *r*	Significance level	Pearson's *r*	Significance level
Age	−.147	.078	.068	.416
Education	−.042	.613	**.200**	**.016**
Duration of illness	−.034	.688	**−.177**	**.036**
Crystallized Verbal Knowledge	**.249**	**.003**	**.458**	**.001**
PANSS positive symptoms (*N* = 142)	**−.186**	**.033**	.055	.527
PANSS negative symptoms (*N* = 142)	.101	.249	−.117	.179
HAM-D-17 total (*N* = 135)	**−.254**	**.003**	−.013	.885
UPSA total score (*N* = 131)	.111	.206	**.364**	**.001**

Note: PANSS, Positive and Negative Syndrome Scale; HAM-D, Hamilton Depression Rating Scale—17-item total. Cognitive flexibility comprises Trails Number-Letter Switching, Design Fluency—Switching, Color-Word Interference Inhibition, and Inhibition/Switching. Abstraction comprises Sorting, Twenty Questions, Word Context, and Proverb. The 2 components share 9.3% of the variance. Where not specifically mentioned, *N* = 145.

significantly related to either factor. Crystallized verbal knowledge was positively correlated with both cognitive flexibility and abstraction, but the magnitude of the correlation appeared to be much larger for abstraction. Abstraction had a significant (moderate effect size) correlation with UPSA total score.

Discussion

The goal of this study was to determine whether executive functions represent a unitary construct in schizophrenia. In the present sample of clinically stable community-dwelling individuals with schizophrenia, we found that each of 10 executive function tasks could be subsumed under one of two separable subdomains, ie, cognitive flexibility (or perhaps timed) tasks and abstraction. After accounting for processing speed (and therefore the timed vs untimed component), we found that most of the tasks could still be subsumed under the two separable domains with little overlap, ie, cognitive flexibility and abstraction. The two factors, even with processing speed accounted for, showed differential relationships with education levels and severity of psychopathology. Crystallized verbal skill was positively related to both constructs, but the magnitude of this relationship was stronger with abstraction than with cognitive flexibility.

Another key finding was that better abstraction, but not cognitive flexibility, was significantly associated with better functional capacity. This is notable for several reasons. Outside the specific arena of schizophrenia research, some of the proposed models of executive functions have emphasized flexibility, response inhibition, and updating of working memory, without reference to abstraction (eg, Miyake et al[28]). Within contemporary schizophrenia literature, there has been a tendency to conflate the two constructs due to the nature of the specific measures employed. In particular, the Wisconsin Card Sorting Test (WCST) is the single most widely used measure in literature on the neuropsychology of schizophrenia, with 483 publications on "Wisconsin Card Sorting" and "schizophrenia" from 1951 to August, 2010 indexed in PubMed. Performance on this measure is clearly dependent both upon cognitive flexibility as well as upon abstract reasoning skills.[1] In clinical applications with individual patients, it may be possible to distinguish effects from the two constructs by examining the conceptual level response as well as perseverative error scores; however, in research, most investigators generally choose a single WCST score for use in the analyses. Thus, although it would be inaccurate to say that the construct of abstraction has been ignored in neuropsychological studies of schizophrenia,[4] there has been little concerted effort to disentangle abstraction and cognitive flexibility as separable constructs within such studies.

The fact that functional capacity was associated with abstraction, but not with cognitive flexibility, also illustrates the potential pragmatic utility of differentiating among these two types of executive functions in treatment planning or needs assessment. For instance, the Consensus Battery from the Measurement and Treatment Research to Improve Cognition in Schizophrenia (MATRICS) initiative was originally designed only to provide a common battery to test potential cognitive enhancement interventions in schizophrenia. However, this battery seems to be emerging as the default battery for a wider array of neurocognitive studies of schizophrenia. Thus, it is notable that, other than working memory tasks and letter/category fluency, the only executive function task on the MATRICS battery is the Mazes task, which appears sensitive to planning as well as processing speed but has no clear abstraction component. Given the pattern of associations seen in the present study in terms of predictors of functional capacity, supplementing the MATRICS battery with one or more measures of abstraction may be warranted when endeavoring to use cognitive test scores to predict functional capacity.

Although separate consideration of abstraction has been missing from many contemporary studies of schizophrenia, the present findings hearken back to research on "concrete thinking" and impairment in "abstract attitude" that characterized much of the psychological research earlier in the last century on the thinking patterns characterizing schizophrenia.[7] Individuals with schizophrenia have been clinically noted as having concrete thinking from the time of Kraepelin.[3,29] However, with some notable exceptions[30] (including Kraepelin himself, who specifically suggested a link between such impairments and pathology in the frontal brain regions[8]), the abstraction impairment in schizophrenia was linked to psychological and psychodynamic[31] constructs throughout much of the 20th century, with limited reference to brain regions that might underlie such skills.[6]

There is relatively little discussion about cognitive flexibility in historical writings (compared with early research and commentary on abstraction deficits in schizophrenia), but deficits in cognitive flexibility in schizophrenia, particularly as measured by the Trail Making Test-Part B, have been widely studied over the last several decades.[32,33] Cognitive flexibility is consistently impaired in people with schizophrenia compared with normal comparison participants[34] and typically, because tests such as the Trail Making are multifactorial, it is difficult to determine the role of underlying cognitive processes.

Although the two factors identified in the present study are roughly consistent with those reported by Clarke et al,[19] the present findings represent a substantive advance beyond those initial findings in that we were able to adjust for the potential confounding effects of method variance.[20] In the present study, we not only demonstrate that the dichotomy between abstraction and mental flexibility is not merely one of timed vs untimed tests but also that the two factors have differential relationships to functional capacity. The latter finding suggests that the distinction between abstraction and mental flexibility is not merely one of theoretical interest but also one that may have importance in applied/clinical settings, particularly in the context of determining capacity for independent living, vocational rehabilitation, and other long-term care needs.

One potential limitation of the present study, reflecting the broad construct of executive functions, is that even the D-KEFS, as the most comprehensive standardized instrument of these skills, still may not cover all aspects of the construct. For instance, there may be some behavioral manifestations of executive dysfunction that do not strongly correlate with those aspects emphasized in psychometric/neuropsychological tests of this construct.[35] Thus, it is possible that there are more than two meaningful components of executive dysfunction in schizophrenia. However, those other components are likely ones that are going to be best captured by behavioral rating scales rather than neuropsychological instruments.[35]

The present findings are noteworthy in several respects. We were able to control for processing speed in schizophrenia while examining dimensions of executive functions in schizophrenia. The components of executive functions of the D-KEFS showed differential relationships with relevant demographic and clinical variables, as well as functional capacity, and had minimal overlap. From a neuroscience perspective, it would be interesting to examine the relationships between executive functioning, as well as other neurocognitive functions, and potential mediating neural pathways, particularly frontal-subcortical circuits[36] and their genetic and epigenetic correlates among individuals in schizophrenia on a profile rather than group basis. Because some studies of cognitive function among relatives of persons with schizophrenia have shown subtle impairments in cognitive flexibility and abstraction/concept formation, it is possible that the impairment in these constructs reflects, in part, vulnerability to the condition.[37,38]

To summarize our findings, rather than speaking of executive functions generically and as a homogeneous construct, at least within the context of describing the neurocognitive characteristics of schizophrenia, the present study provides empirical grounding for distinguishing between the constructs of cognitive flexibility and abstraction. This study sheds light on the importance of including measures of cognitive flexibility along with those of abstraction in a comprehensive neuropsychological assessment in schizophrenia and considering the relative strengths and weaknesses within the executive functioning domain to identify targets for rehabilitation planning for patients with schizophrenia. From a clinical perspective, the next step would be to examine the relationships between abstraction and cognitive flexibility and real life functioning among patients with schizophrenia, in areas such as medication adherence, decision-making capacity, driving ability, school and work functioning, and other instrumental activities of daily living, in order to better determine the types of strategies needed for rehabilitation. Overall, the present study illustrates an approach to studying neuropsychological aspects of schizophrenia that may permit clearer differentiation of specific cognitive constructs, and thereby permit the field to move beyond statements about the effects of generalized cognitive dysfunction, and instead examine more specific cognitive processes, which have tighter associations with known neurobiological systems.

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Supplementary Material

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