Original Article

Evaluating the Dimensionality of Perceived Cognitive Function

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Abstract

Decrements in cognitive function are common in cancer patients and other clinical populations. As direct neuropsychological testing is often not feasible or affordable, there is potential utility in screening for deficits that may warrant a more comprehensive neuropsychological assessment. Furthermore, some evidence suggests that perceived cognitive function (PCF) is independently associated with structural and functional changes on neuroimagery, and may precede more overt deficits. To appropriately measure PCF, one must understand its components and the underlying dimensional structure. The purpose of this study was to examine the dimensionality of PCF in people with cancer. The sample included 393 cancer patients from four clinical trials who completed a questionnaire consisting of the prioritized areas of concerns identified by patients and clinicians: self-reported mental acuity, concentration, memory, verbal fluency, and functional interference. Each area contained both negatively worded (i.e., deficit) and positively worded (i.e., capability) items. Data were analyzed by using Cronbach's alpha, item-total correlations, one-factor confirmatory factor analysis, and a bi-factor analysis model. Results indicated that perceived cognitive problem items are distinct from cognitive capability items, supporting a two-factor structure of PCF. Scoring of PCF based on these two factors should lead to improved assessment of PCF for people with cancer. J Pain Symptom Manage 2009;37:982–995. *© 2009 U.S. Cancer Pain Relief Committee. Published by Elsevier Inc. All rights reserved.*

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Introduction

Changes in cognitive function occur in normal aging,[1,2] but also can be associated with a number of chronic illnesses, such as epilepsy[3,4] multiple sclerosis,[5] Alzheimer's disease,[6] and cancer.[7,8] Traditionally, cognitive function has been described and measured by its component processes, such as memory, attention, and executive functioning. Consequently, cognitive function often has been assessed using flexible or fixed batteries of neuropsychological tests, which provide objective measures targeting either specific cognitive components, specific neurological disorders, or cognitive functioning more globally.[9,10] Despite well-known advantages, direct neuropsychological testing is often not feasible or affordable. As a result, patients are typically referred for neuropsychological testing only after significant decrements are noticed. Furthermore, when such batteries are administered repeatedly, their reliability and validity are likely to be compromised by practice effects. These limitations have prompted interest in the use of screening tools to identify individuals who may benefit from a full neuropsychological battery. A psychometrically sound instrument measuring self-reported cognitive function, that is, perceived cognitive function (PCF), may fill this need.

The concept of PCF has been discussed in the research literature using different terms, such as cognitive complaints,[11] cognitive difficulties,[12] cognitive distress,[13] or subjective cognitive dysfunction;[14] however, the validity of PCF measures often has been questioned.[15,16] Examples of such criticisms are that patients with declining cognitive function are unlikely to report reliably on their cognitive function;[17] and that PCF may reflect patients' psychological states (e.g., depression) rather than cognitive function.[18,19] Although the association between PCF and performance-based neuropsychological testing results has been inconsistent,[3,20–22] recent evidence suggests that PCF is independently predictive of structural or functional brain changes, and may precede more overt deficits.[23–31] For example, Saykin et al.[26] compared structural brain magnetic resonance imaging scans across three groups: individuals with cognitive complaints but with normal neurological test performance (CC), patients with amnestic mild cognitive impairment (MCI), and individuals without significant cognitive complaint or deficits. They found that CC and MCI groups showed a similar pattern of reduced gray matter density in the bilateral medial temporal, frontal, and other distributed brain regions. This study highlights the importance of PCF in the clinical evaluation of older adults, suggesting that those who report cognitive decrements may warrant evaluation and/or close monitoring over time. As new treatment and preventive strategies for MCI and Alzheimer's disease are developed and refined, the earliest possible accurate detection of patients at increased risk of developing diseases will take on critical importance. This further highlights the importance of having a reliable yet user-friendly PCF instrument. The purpose of such a tool would not be to replace a comprehensive neuropsychological testing battery; instead, it may serve as a useful screening tool that could be used in clinics to identify individuals who may benefit from a more thorough neuropsychological evaluation or more frequent monitoring for cognitive changes.

Recognizing the potential clinical utility of the construct, the cancer supplement to the National Institutes of Health Patient-Reported Outcomes Measurement Information System (PROMIS: http://www.nihpromis.org) has included PCF as one of its measurement development areas. The current version of the PROMIS Cancer Supplement PCF measure comprises 78 items, including items from the Functional Assessment of Cancer Therapy-Cognition (FACT-Cog, version 2), the scale we focus on in the current analysis. An appropriate measure requires a full understanding of the underlying latent trait the PCF intends to measure. As a first approximation to address this issue, we examined the dimensionality of PROMIS PCF items by using bi-factor analysis, a recently developed technique for examining unidimensionality of item sets. Given the documented effects of cancer and chemotherapy

on cognitive function,[7,8] we felt it would be appropriate to first address this issue in a cancer population. We started with a cancer sample to reduce some of the variability in the association of PCF with neuropsychological testing across patient groups.

Methods

Measure

The development process of the FACT-Cog has been reported elsewhere.[32,33] Items for the scale were written to reflect themes identified by experts and patients and literature-review results. To minimize self-report bias because of distress unrelated to cognition, items were written to include behavioral examples of cognitive dysfunction. As a result, FACT-Cog Version 1 consisted of 35 items that were rated on a 5-point Likert scale.[32] We then administered this measure to 206 general oncology patients. Most of the patients in that sample were whites (93.2%) and females (59.2%), with a mean age of 59.6 ± 13.0 years. Approximately 26% of patients had breast cancer, 15% had colorectal cancer, and 14% had non-Hodgkin's lymphoma; most of the patients were receiving chemotherapy at that point (89.8%). Reliability was excellent ($\alpha = 0.96$). Psychometric properties of individual items were examined by using a one-parameter item response theory (IRT)-Rasch model.[34] Items were determined to fit if the ratio between expected and observed item variance was less than 1.4 (i.e., infinite mean square[MnSq] < 1.4 in Rasch software output). Results showed that one item did not fit and three items provided information redundant with other items, as demonstrated by high item-total correlations and further discussions with a group of experts. Consequently, one item was revised and three items were removed from the scale. Additionally, 10 new, positively worded items were developed to reduce an observed ceiling effect. As a result, the FACT-Cog (v2) consists of 42 items (32 negatively worded and 10 positively worded).

To reflect patients' experience, the FACT-Cog (v2) items were originally grouped into two categories: *cognitive capacity* and *cognitive performance*. *Cognitive capacity*, including both items capturing capability and deficit, consists of the following four areas of concerns: *mental acuity* (four items), *concentration* (four items), *verbal and nonverbal memory* (seven items), and *verbal fluency* (seven items). *Cognitive performance*, defined as actual performance or consequence of a given capability or deficit item, consists of the following three areas of concerns: *functional interferences because of cognitive deficits* (seven items), *noticeability* (four items), and *changes in cognitive function* (nine items). A frequency type of rating scale is used (0 = never; 4 = several times a day). FACT-Cog (v2) items are listed in the Appendix.

Samples

This is a secondary analysis, making use of data from 393 cancer patients who participated in studies at Evanston Northwestern Healthcare, University of Toronto-Princess Margaret Hospital, University of Pennsylvania-Abramson Cancer Center, and Moffitt Cancer Center and Research Institute. The Institutional Review Board at each site approved the study before patients were approached, and all participants provided written informed consent. Patient demographic and clinical information are summarized in Table 1. Across the entire sample, 65.1% were female, average age was 53.8 years (standard deviation [SD] = 12.5), and 57.2% had a college degree or higher. Most of the sample members had breast cancer (54.5%), followed by multiple myeloma (16.0%), prostate cancer (9.4%), testicular cancer (5.9%), and colorectal cancer (5.6%). None of the patients had a central nervous system-related tumor/cancer. Patients were at different stages of the disease continuum ranging from on-treatment to long-term survival. Because of the research goals across the study sites, the available treatment information is variable. Nearly half of the sample members ($n = 149$; 45.6%) were known to receive chemotherapy or had completed chemotherapy.

One hundred and one (30.8%) patients completed the FACT-Cog at either six or 12 months post bone marrow transplant; 51 (15.6%) patients underwent surgery or radiation without chemotherapy; 26 (8.0%) prostate patients received androgen-deprivation therapy only (either a leutinizing hormone-releasing hormone[LHRH] agonist or complete androgen blockade). In addition to the PCF items, patients also completed various

Table 1
Sample Demographic and Clinical Information

Variable	Total *n* (%)[a]	By Data Source: Source 1 (*n* = 62), *n*	Source 2 (*n* = 101), *n*	Source 3 (*n* = 188), *n*	Source 4 (*n* = 42), *n*
Age, mean (SD)	53.8 (12.5)	50 (9)	53 (12)	55 (14)	60 (7)[b]
Gender					
Male	137 (34.9)	2	57	60	18
Female	256 (65.1)	60	44	128	24
Education					
High school or less	84 (24.1)	5	47	32	0
Some college	65 (18.7)	13	25	27	0
College degree or higher	199 (57.2)	44	29	126	0
Unknown	45 —	0	0	3	42
Diagnosis					
Breast	214 (54.5)	62	4	128	20
Colorectal	22 (5.6)	0	0	0	22
Multiple myeloma	63 (16.0)	0	63	0	0
Non-Hodgkin's lymphoma	12 (3.1)	0	12	0	0
Prostate	37 (9.4)	0	0	37	0
Testicular	23 (5.9)	0	0	23	0
Other	22 (5.6)	0	22	0	0
Ethnicity					
Hispanic origin	8 (2.3)	0	6	2	0
White	282 (82.5)	47	87	148	0
African American	33 (9.6)	5	6	22	0
Other	19 (5.6)	10	2	7	0
Unknown	51 —	0	0	9	42
Treatment					
Chemotherapy	149 (45.6)	62	0	87	0
Surgery/radiation with no chemotherapy	51 (15.6)	0	0	51	0
BMT	101 (30.8)	0	101		0
ADT	26 (8.0)	0	0	26	0
Information not available	66 —	0	0	24	42
Assessment Timing		On Cycle 4, Day 1 of Treatment	6 or 12 Months Post-BMT	Vary with Diseases[c]	Received Cancer Treatment Within 6 Months
FSIQ, mean (SD)	112.2 (7.4)	110 (6)		114 (8)[d]	
Quality of life, mean (SD)					
PWB[e]	22.29 (5.5)	18.06 (6.3)	—	23.34 (4.7)	25.05 (2.7)
EWB	19.06 (4.3)	18.95 (4.3)	—	18.91 (4.4)	20.67 (3.2)
SWB	22.10 (5.2)	23.42 (4.3)	—	21.56 (5.3)	23.19 (5.8)
FWB	19.99 (5.6)	18.12 (5.6)	—	20.29 (5.5)	22.57 (6.2)
SF-36-Mental	52.33 (10.7)	—	52.33 (10.7)	—	—
SF-36-Physical	38.90 (10.3)	—	38.90 (10.3)	—	—

BMT = bone marrow transplant; ADT = androgen-deprivation therapy.
[a]Percentage was calculated by excluding data that were unavailable.
[b]$n = 20$.
[c]All testicular cancer patients had survived for at least 2.5 years (mean = 7.4 years) at the time of surveying. All prostate cancer patients did not undergo chemotherapy and treatment dates are not available. Breast cancer patients were undergoing chemotherapy at the time of surveying.
[d]$n = 60$.
[e]PWB: FACT-G physical well-being (norm = 22.7, SD = 5.5); EWB: emotional well-being (norm = 19.9, SD = 4.8); SWB: social/family well-being (norm = 19.1, SD = 6.8); FWB: functional well-being (norm = 18.5, SD = 6.8).

performance-based cognitive instruments. Although cognitive instruments were not consistent across the samples, three subsets of the sample ($n = 122$) had estimates of Full-Scale Intelligence Quotient (FSIQ) available (mean FSIQ = 112.2; SD = 7.4). Compared with the population norm of 100 and SD = 15, 74 patients (60.6%) were within 1 SD of the mean (6 below and 68 above the mean), 47 (38.5%) were 1 SD above and only one (0.8%) was 1 SD below. Sample information by study is detailed in Table 1. Sixty-two patients completed the Hospital Anxiety and Depression Scale (HADS); the average depression score was 4.44 SD = 3.97 and the average anxiety score was 5.24 (SD = 3.90). Quality of life was measured using either the FACT-General (FACT-G)[35] or the SF-36.[36] The average quality-of-life scores are reported in Table 1. The sample had physical composite scores (as measured in SF-36) at least one SD lower than the national norms.[36] However, the sample had similar physical well-being (part of FACT-G), emotional well-being (EWB; part of FACT-G), and SF-36 mental composite scores compared with national norms.[36,37] The sample reported higher social well-being (part of FACT-G) and functional well-being (part of FACT-G); nevertheless, they were within 1 SD of normative means.

Analysis

We first evaluated the coherence of items within each area of concern (e.g., memory, concentration) using Cronbach's alpha (criterion: ≥0.7) and item-total correlations (criterion: >0.3). Next, we used one-factor confirmatory factor analysis (CFA)-related techniques to evaluate dimensionality using the original FACT-Cog item categories (i.e., cognitive capacity and cognitive performance). Unidmensionality[38] at the subdomain level was confirmed when the model fit the data well (i.e., comparative fit index, CFI > 0.9; Tucker-Lewis index, TLI > 0.90) and the loadings of all the items are sufficiently large (loading > 0.3).

Finally, bi-factor analysis was used to examine sufficient (or "essential") unidimensionality at the domain level (i.e., overall PCF).[39,40] We have used such an approach in the past to demonstrate that although cancer-related fatigue manifests itself in a number of different ways (e.g., physical fatigue, mental fatigue), it is essentially unidimensional using a bi-factor analysis and, therefore, can be described using a single score.[39] Bi-factor analysis includes two classes of factors: a general factor, defined by loadings from all of the items in the scale, and local factors, defined by loadings from prespecified groups of items related to that subdomain.[40–43] The relationship between general and local factors are orthogonal, as the local factors are related to the contribution that is over and above the general factor. This approach permits each parameter in the model to be uniquely estimable so that, theoretically, there should not be problems with identification. Items are considered sufficiently unidimensional when standardized loadings are salient (i.e., >0.3) for all the items on the general factor. Similarly, if the loadings of all the items on a local factor are salient, it would indicate that the local factor is well defined even in the presence of the general factor, where it is more appropriate to report scores of local factors separately.[39,40] The bi-factor analysis was conducted by using MPlus version 3 (Muthen & Muthen, CA)[42] with the implementation of the polychoric correlation matrix and weighted least squares with adjustments for mean and variance estimation, which is appropriate for the evaluation of ordered categorical data.

Additionally, to better understand the measurement properties of cognitive capability (i.e., positively framed) and cognitive deficiency (i.e., negatively framed) items, we examined the sociodemographic correlates of both classes of item. SAS 9.1(SAS Institute, NC)[44] was used for these analyses.

Results

All negatively worded items were reverse-scored, that is, higher scores on the FACT-Cog items always represent better function. Descriptive statistics showed that all response categories (i.e., 0 = never; 4 = several times a day) were used for each item, with means ranging from 2.2 (SD = 1.5) for the item "My thinking is fast as always" to 3.9 (SD = 0.4) for the item "accidentally missed medical appointments."

Results of Seven "Areas of Concern"

Table 2 shows analysis results of each area of concern. Cronbach's alphas ranged from 0.49

Table 2
Analysis Results: Areas of Concern

Area of Concern	Item n (Negative)	Item n (Positive)	Alpha of All Items	Negatively Worded (Deficiency) Items Only	
				Alpha	Item-Total Correlation
Mental acuity	3	1	0.72	0.92	0.81-0.84
Concentration	3	1	0.49	0.69	0.48-0.51
Memory	5	2	0.70	0.81	0.43-0.72
Verbal fluency	6	1	0.83	0.91	0.65-0.81
Functional interference	6	1	0.77	0.81	0.32-0.66
Noticeability	3	1	0.74	0.87	0.71-0.81
Changes in cognitive functions	6	3	0.89	0.93	0.63-0.87

(concentration) to 0.89 (changes in cognitive function). However, positively framed items measuring cognitive capability had low item-total correlations (range: 0−0.17) in all but one concern area and low Spearman rho (0−0.25) compared with negatively framed items measuring cognitive deficit. The one exception to this pattern was the changes in cognitive function, which consists of three capability items, with item-total correlations of either 0.47 or 0.51. However, the Spearman rho of these three capability items with the remaining deficit items of the same area of concern ranged from 0.13 to 0.25; the rho within these three items ranged from 0.86 to 0.90. Therefore, we concluded that the moderate item-total correlations were the result of including these three highly correlated capability items in the same area of concern, not because they correlated with other items measuring cognitive deficits. As shown on Table 2, alpha values increased when items measuring cognitive capability were excluded.

Given the consideration that alpha is influenced by the number of items in the scale, the fact that higher alpha values were obtained with fewer items indicated that capability items and deficit items should not be scaled together. Consequently, we regrouped items into three subdomains. Positively framed cognitive capability items, originally grouped with negatively framed deficit items under the cognitive capacity item category, were used to form a distinct subdomain: *cognitive capabilities.* Internal consistency of these 10 capability items was supported by high internal consistency ($\alpha = 0.91$) and item-total correlations ranging from 0.48 to 0.74. The cognitive deficit items that remained under the original cognitive capacity category were grouped into a separate, renamed subdomain: *cognitive deficits.* To reflect the specific nature of the original cognitive performance item category, the remaining item grouping was renamed under the subdomain name *consequences of cognitive deficits.*

Results of Three Subdomains

We then tested the unidimensionality of three subdomains: cognitive deficit, consequences of cognitive deficits, and cognitive capabilities. CFA results (shown in Table 3) supported the unidimensionality of each subdomain: CFI = 0.90, 0.92, 0.92 and TLI = 0.97, 0.98, 0.95 for cognitive deficits, consequences of cognitive deficits, and cognitive capability, respectively. Though root mean square error

Table 3
Dimensionality Testing Results: Local Factors (Grouped Subdomains)

Local Factor	Item n	Alpha	Item-Total Correlation	CFI	TLI	RMSEA
Cognitive deficits[a]	17	0.94	0.43-0.79	0.90	0.97	0.167
Consequences of cognitive deficits[b]	15	0.92	0.29-0.86	0.92	0.98	0.155
Cognitive capabilities[c]	10	0.91	0.48-0.74	0.92	0.95	0.380

[a]Cognitive deficits consist of items measuring mental acuity, concentration, memory, and verbal fluency.
[b]Consequences of cognitive deficits consist of items measuring functional interference, other people notice, and changes in cognitive functions.
[c]Cognitive capabilities consist of all positively worded items.

Table 4
Factor Loadings of Each Item to the General Factor and to Its Associated Local Factor

Item		Local Factor/Subdomain	Factor Loading[a] Overall PCF	Local Factor
COGA1	Cognitive Deficits	*Mental Acuity*	0.84	0.26
COGA3			0.89	0.30
COGA4			0.86	0.37
COGC5		*Concentration*	0.65	0.07
COGC6			0.69	−0.18
COGC7			0.76	0.30
COGM8		*Memory*	0.68	−0.19
COGM9			0.59	−0.23
COGM10			0.62	−0.15
COGM11			0.78	−0.21
COGM12			0.83	−0.13
COGV13		*Verbal Fluency*	0.83	−0.28
COGV14			0.85	−0.25
COGV15			0.89	−0.21
COGV16			0.70	−0.25
COGV17A			0.85	−0.10
COGV17B			0.85	−0.09
COGF19	Consequences of Cognitive Deficits	*Functional Interference*	0.76	−0.09
COGF20			0.66	−0.13
COGF21			0.50	−0.15
COGF23			0.80	0.28
COGF24			0.73	0.03
COGF25			0.76	0.28
COGO26		*Noticeability*	0.75	0.32
COGO27			0.74	0.34
COGO28			0.78	0.41
COGC29		*Changes in Cognitive Function*	0.86	0.31
COGC31			0.84	0.44
COGC32			0.86	0.40
COGC33A			0.89	0.31
COGC33B			0.85	0.27
COGC33C			0.69	0.11
COGPA1	Cognitive capabilities		0.10	0.85
COGPC1			0.04	0.85
COGPM1			0.02	0.80
COGPM2			−0.01	0.84
COGPV1			−0.10	0.61
COGPF1			0.23	0.75
COGPO1			0.22	0.73
COGPCH1			0.34	0.89
COGPCH2			0.33	0.90
COGPCH3			0.30	0.88

[a]Standard errors of each loading are between 0.01 and 0.06.

of approximation (RMSEA) ranged from 0.16 to 0.38, given the acceptable TLI and CFI values, we still considered unidimensionality of each subdomain.

Results of Entire Domain (Bi-Factor Model)

We then examined the general PCF domain for sufficient unidimensionality by using bi-factor analysis. We conceptualized the general factor as "overall PCF" and local factors as the previously described subdomains: cognitive deficits, consequences of cognitive deficits, and cognitive capabilities. All items were loaded on both the general factor and their own local factor.

Table 4 shows results of the bi-factor analysis, which compares factor loadings of all items on the general factor and on the subdomain

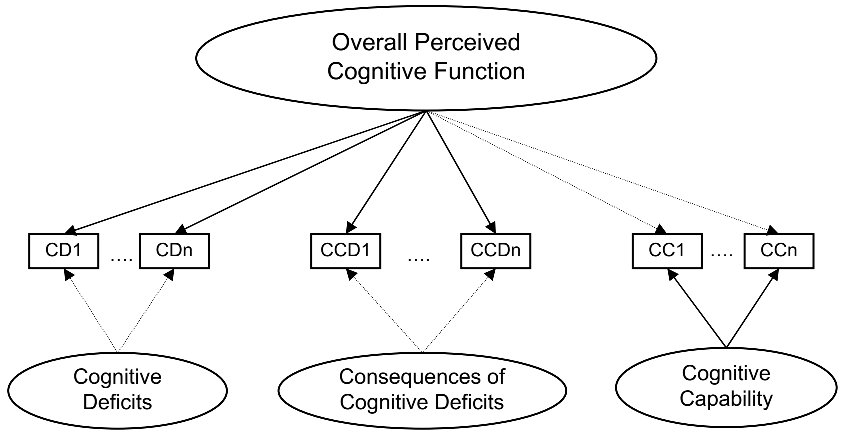

Fig. 1. Relationship between the general factor (overall PCF) and local factors (cognitive deficits, consequences of cognitive deficits, and cognitive capabilities). Note: 1) Bi-factor analysis results show that all items of cognitive deficits and consequences of cognitive deficits have higher loadings (solid lines) on the general factor overall PCF rather than on their own local factors (dashed lines), whereas all cognitive capability items have higher loadings on their local factor (solid lines) than on the general factor (dashed lines). Comparisons of item loadings are shown on Table 3. 2) Model fit: CFI = 0.92 and TLI = 0.98; RMSEA = 0.120.

factors. Acceptable CFI (=0.92) and TLI (=0.98) were obtained in this analysis. The RMSEA of 0.120, lower than when local factors were considered individually, indicated that the general factor model fit data better. Figure 1 depicts the relationship between local factors (i.e., subdomains) and the general factor.

Cognitive deficits and consequences of cognitive deficits items had higher loadings (from 0.50 to 0.89; shown as solid lines in Fig. 1) on the general factors than those on the local factors (from −0.28 to 0.44; shown as dashed lines in Fig. 1). Although some items had loadings of 0.3 or more on both the general and local factors (three measured cognitive deficits and seven measured consequences of cognitive deficits), their loadings on the general factor were much higher than those on local factors (loading discrepancy ranged from 0.37 to 0.59). On the other hand, items of the perceived cognitive capabilities subdomain had higher loadings (from 0.61 to 0.90; shown as solid lines in Fig. 1) on the local factor than on the general factor (from −0.10 to 0.34; shown as dashed lines in Fig. 1). For cognitive deficits and consequences of cognitive deficits, the negative loadings of some items on the local factors indicated that our a priori theoretical model of how the local factors might relate to the items was not compatible with the data. However, this does not have any bearing on the validity of treating items in the cognitive deficits and consequences of cognitive deficits subdomains together as sufficiently unidimensional for later applications requiring unidimensionality, such as the IRT model. This subdomain is called perceived cognitive problems.

Distinct from items measuring cognitive problems, perceived cognitive capability items loaded higher on the local factor than on the general factor (loading discrepancy range: −0.50 to −0.85). In other words, although perceived cognitive capability items perform well together, they do not measure the same construct as perceived cognitive problems. From a psychometric perspective, cognitive problems and cognitive capability are separate constructs under the umbrella of PCF.

Other Related Analyses

The magnitude of the correlation between cognitive capability and cognitive problems was negligible: Pearson $r = 0.106$, $P = 0.035$; Spearman's rho = 0.158, $P = 0.002$. Cognitive capability and problem items were not significantly correlated to age, $r = 0.059$ ($P = 0.261$) and −0.014 ($P = 0.790$), respectively. There was no significant difference in the cognitive problem scores between gender ($t = 1.65$, $P = 0.10$) and education (college degree or higher compared with those without; $t = -0.32$ $P = 0.75$). However, we found females (vs. males) and patients who had at least

a college degree (compared with those who did not) had better cognitive capability scores of $t = 3.28$ ($P = 0.001$) and 5.03 ($P < 0.001$), respectively. Patients who had FSIQ scores available were divided into four groups (2 SDs below norm, 1 SD below norm, 1 SD above norm, 2 SDs above norm). There was no statistically significant difference in scores among groups on items measuring cognitive problems ($F_{(3,118)} = 0.91$, $P = 0.44$) or capability ($F_{(3,118)} = 1.41$, $P = 0.24$). The aforementioned results suggest that patients perceived their cognitive problems and cognitive capability independently regardless of FSIQ. These results strengthened our conclusion that cognitive problems and capability are two distinct concepts.

Patients with better scores on the EWB scale of the FACT-G[35] (available $n = 268$) tended to report less cognitive problems and better capability, with Spearman's rho = 0.41 and 0.24 ($P < 0.001$), respectively. Similar results were found with the relationship between the SF-36 mental component score (MCS) (available $n = 99$) and cognitive problems (rho = 0.35, $P < 0.001$), but not cognitive capability (rho = −0.25, $P = 0.014$). Patients ($n = 62$) with less cognitive problems and better cognitive capability reported less depression and anxiety as measured by HADS—rho = −0.69 and −0.49 for problems, respectively, and rho = −0.37 and −0.32 for, perceived cognitive capability, respectively.

Discussion

Cancer and cancer treatment can have a deleterious impact on cognition. Only in the past 10−15 years have clinical researchers examined and documented this phenomenon in any rigorous way.[8,45,46] However, chemotherapy-associated cognitive decline and the mechanisms underlying this phenomenon are not yet well understood. A valid PCF-measurement tool can assist clinicians communicating with their patients about their cognitive concerns and can serve as a useful screening tool to identify patients who may benefit from a referral for a more comprehensive neuropsychological test. Toward this end, it is crucial to understand the dimensionality of PCF to determine whether it is appropriate to report a single summary score or multiple scores tapping relevant content areas separately.[39] Based on evidence from internal consistency statistics, confirmatory factor-analytic techniques (including bi-factor analysis), and a negligible correlation between cognitive capability and cognitive problem items, we conclude that these sets of items are perceived by cancer patients as distinct factors and their scores should be reported separately.

Results of this study were somewhat unexpected. Positively worded (i.e., cognitive capability) items were initially added to an earlier version of FACT-Cog to minimize a ceiling effect—a common practice in test/scale construction. Our experiences in other health-related quality-of-life measures have shown that such a strategy is valid, at times. For example, we have shown that vitality or energy items (i.e., positively worded "fatigue" items) tap the same construct as fatigue items; the added energy items appeared to cover the higher end (i.e., less fatigue) of the symptom continuum.[47] On the other hand, negatively worded illness-impact items did not seem to measure the same construct as the positively worded ones. In fact, similar to our present findings, the relationship between positive and negative illness-impact items was found to be orthogonal.[48] We reasoned that our findings in PCF and illness impact, unlike cancer-related fatigue, may share similarities with the measurement of affect, where positive and negative aspects are essentially independent.[49−51] We, therefore, conclude that there are two relatively unrelated concepts that comprise PCF: *Perceived cognitive problems*, defined as perceived cognitive deficits and the consequences of those difficulties, and capability, including items that tap self-efficacy and confidence. At this time, we cannot completely rule out the possibility that method variance captured by the local factors define the distinction we have made between cognitive capability and, perceived cognitive problem items, and hence, results from the present analyses require replication.

Previous research has suggested that depression and anxiety may have strong associations with subjective memory difficulties. Neuropsychological test performance may not be associated with patient-reported cognition after controlling for the impact of emotional distress.[28] In this study, for those with available

data, we found an association between the perceived cognitive problems scale and mood measures. However, similar correlations with cognitive capability were inconsistent. It is somewhat difficult to determine if the different patterns of results for cognitive problems and cognitive capability are a result of true differences in the subscales or an issue related to the different instruments used to assess emotional health symptoms (e.g., EWB subscale of FACT-G vs. MCS of SF-36). The implementation of initiatives, such as NIH PROMIS, may help to standardize such assessments, making such comparisons more straightforward. Nonetheless, it is possible that PCF may reflect emotional distress more than cognitive dysfunction, as measured by performance-based measures.

However, we feel that PCF is an important patient-reported outcome in its own right. Of note, even when mood symptoms were associated with the PCF subscale, the shared variance between the two concepts was not substantial. Our PCF measure assesses something above and beyond symptom distress and taps concerns of importance to cancer patients. Some evidence suggests that PCF instruments may be associated with brain changes detectable using structural or functional neuroimagery.[23–31] In addition to the study conducted by Saykin et al.,[26] as mentioned earlier, de Groot et al.[25] found that cognitive complaints (i.e., perceived cognitive problems) preceded measurable cognitive dysfunction or even dementia. A dose-dependent pattern was suggested: at the lower end of the white matter lesion (WML) severity distribution are subjects without reported cognitive problems and good cognitive performance, followed by those with reported cognitive problems but without cognitive dysfunction on neuropsychological testing, and finally those with reported cognitive problems progression during the last five years and measurable cognitive dysfunction. Perceived cognitive problems might be an early warning sign related to the progression of WML and imminent cognitive decline. Although the results from Saykin et al. and de Groot et al. are compelling, we do not claim that PCF is a superior measure of cognition than neuropsychological tests, but PCF may hold promise, in specific circumstances, as a marker of structural or functional changes in the brain.

A psychometrically sound PCF scale will assist in our understanding of how patients' self-reported cognition relates to objective performance and to other important correlates, such as emotional distress. For the present samples, we did not have information on patients' objective neuropsychological test performance to compare with PCF scores. However, to help elucidate this important issue, we plan to apply a multitrait, multimethod approach[52] to explore the construct validity of PCF with longitudinal data currently being collected. Such a systematic approach will aid in our understanding of what we are measuring when we ask patients about their cognitive functioning.

A few other questions remain unanswered. Patients did not differ with respect to their scores on the perceived cognitive problems items based on sex, education, or IQ. However, females and college-educated patients had better cognitive capability scores than the comparison groups. Interestingly, for those patients with IQ estimates, there were no differences between groups on cognitive capability items. The underlying reason for these group differences is not yet clear. To our knowledge, there are no published reports documenting gender difference and education effects on perceived cognitive capability. Future studies should be conducted to further understand potential mediating or moderating factors influencing PCF (both problems and capability).

Although additional research is necessary to better understand what is being measured by cognitive capability items, there are some interesting potential applications for this subdomain of PCF items. For example, it may be the case that cognitive capability items are more responsive to cognitive improvement (e.g., postchemotherapy), compared with problem items, which may be more responsive to cognitive injuries. If so, capability and problem items could serve as complementary but distinguishable indexes of change. Divergent and convergent validity studies using both classes of PCF items may help gauge the degree to which these items tap distinguishable concepts.

The current sample members were well educated, with nearly 60% having at least a college degree. Participants with more educational attainment scored better on cognitive capability items, whereas no significant differences

were found between patients with different levels of FSIQ scores. It is unclear what it is about education attainment that influences patients' perceptions. Future studies that recruit individuals with a greater range in education level are needed to better address such issues. We also note that PCF scores are not normally distributed; however, we do not expect that this impacted the resulting factor pattern. Skewed responses on Likert-type scale items do not mean that the resulting factors must be skewed. The observed non-normality may simply be attributed to the extremeness of the item wording, which is the central concept of the IRT models. In IRT, we prefer to include items with different degrees of endorsement to calibrate them on the construct being measured (in this study, PCF).[47,53]

Furthermore, the samples for the present analysis were restricted to patients with cancer, as there is a growing interest in cognitive decrements because of either the disease itself or the treatment, such as chemotherapy (i.e., chemo-brain). However, the actual item content does not reflect symptoms unique or specific to the cancer experience. Nonetheless, additional studies are needed to cross-validate the factor structure of PCF in other populations. In addition, although the tested items were developed by means of individual interviews and focus groups, it is noted that these items do not yet fully cover all relevant constructs within cognition; for example, executive function and multitasking are not queried, and the number of perceived cognitive problems and capability items is not balanced. Using results of this study, our team is currently working on revising the PCF item bank under the Cancer PROMIS supplement as mentioned earlier. We are hoping that a valid and clinically meaningful PCF measure can serve as a foundation for computerized adaptive testing (CAT), which can provide brief yet precise assessments in busy clinics. Routine CAT-based PCF assessment holds promise as an efficient screening tool for patients at risk of developing cognitive dysfunction.

In conclusion, this article examined the dimensionality of PCF in cancer patients, and based on the convergence of several analyses, we concluded that perceivedcognitive problems and capability are two distinct concepts and should be scored separately. The establishment of sufficient dimensionality is an initial step toward further understanding PCF. Such an understanding holds the promise for the development of better screening tools.

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Appendix

Functional Assessment of Cancer Therapy-Cognition (Version 2)

CogA1	I have had trouble forming thoughts.
CogA3	My thinking has been slow.
CogA4	My thinking has been foggy.
CogPA1	I have been able to think clearly.
CogC5	I have had trouble adding or subtracting numbers in my head.
CogPC1	I have been able to concentrate.
CogC6	I have made mistakes when writing down phone numbers.
CogC7	I have had trouble concentrating.
CogM8	I have had trouble remembering the name of a familiar person.
CogM9	I have had trouble finding my way to a familiar place.
CogM10	I have had trouble remembering where I put things, like my keys or my wallet.
CogM11	I have had trouble remembering whether I did things I was supposed to do, like taking a medicine or buying something I needed.
CogM12	I have had trouble remembering new information, like phone numbers or simple instructions.
CogV13	I have had trouble recalling the name of an object while talking to someone.
CogV14	Words I wanted to use have seemed to be on the "tip of my tongue."
CogV15	I have had trouble finding the right word(s) to express myself.
CogV16	I have used the wrong word when I referred to an object.
CogV17a	I have had trouble speaking fluently.
CogV17b	I have had trouble saying what I mean in conversations with others.
CogPV1	I have been able to bring to mind words that I wanted to use while talking to someone.
CogF19	I have walked into a room and forgotten what I meant to get or do there.
CogF20	I have needed medical instructions repeated because I could not keep them straight.
CogF21	I have forgotten or accidentally missed medical appointments.
CogPM1	I have been able to remember things, like where I left my keys or my wallet.
CogF23	I have had to work really hard to pay attention or I would make a mistake.
CogF24	I have forgotten names of people soon after being introduced.
CogPM2	I have been able to remember to do things, like take medicine or buy something I needed.
CogF25	My reactions in everyday situations have been slow.
CogPF1	I am able to pay attention and keep track of what I am doing without extra effort.
CogO26	Other people have noticed that I had problems remembering information.
CogO27	Other people have noticed that I had problems speaking clearly.
CogO28	Other people have noticed that I had problems thinking clearly.
CogPO1	People think my mind is really sharp.
CogC29	It has seemed like my brain was not working as well as usual.
CogC31	I have had to work harder than usual to keep track of what I was doing.
CogC32	My thinking has been slower than usual.
CogC33a	I have had to work harder than usual to express myself clearly.
CogC33b	I have had more problems conversing with others.
CogC33c	I have had to use written lists more often than usual so I would not forget things.
CogPCH1	My mind is as sharp as it has always been.
CogPCH2	My memory is as good as it has always been.
CogPCH3	My thinking is as fast as it has always been.

A 5-point rating scale assessing "in the past 7-day" time frame is used: 0 = Never; 1 = About once a week; 2 = Two to three times a week; 3 = Nearly everyday; 4 = Several times a day