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Fibrofog in Daily Life: An Examination of Ambulatory Subjective and Objective Cognitive Function in Fibromyalgia

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Objective. Perceived cognitive dysfunction in fibromyalgia (FM), "fibrofog," is common. Prior laboratory-based studies have limited our understanding of cognitive function in FM in daily life. The objective of this study was to explore levels of subjective and objective cognitive functioning and the association between subjective and objective aspects of cognition in people with and without FM in the lived environment.

Methods. Participants (n = 50 adults with FM; n = 50 adults without FM, matched for age, sex, and education) completed baseline measures of subjective and objective cognitive functioning (NIH Toolbox). They also completed ecological momentary assessments of cognitive clarity and speed, and tests of processing speed and working memory, via a smart phone app, 5 times/day for 8 days.

Results. On baseline objective measures, the FM group demonstrated poorer cognitive functioning across 3 NIH Toolbox tests. There were no strong correlations between subjective and objective cognitive functioning in both the FM and control groups. In the lived environment, the FM group demonstrated poorer subjective cognition and objective working memory; groups did not differ on processing speed. Momentary ratings of subjective cognitive dysfunction were significantly related to changes in objective processing speed but not working memory, with no group differences.

Conclusion. Findings indicate worse laboratory-based and ambulatory subjective and objective cognitive function for those individuals with FM compared to those without FM. Similar associations between measures of subjective and objective cognitive functioning for the groups suggest that individuals with FM are not overstating cognitive difficulties. Future research examining contributors to ambulatory fibrofog is warranted.

INTRODUCTION

Approximately 5 million adults in the US are diagnosed with fibromyalgia (FM), a musculoskeletal disorder where pain is usually accompanied by a constellation of physical and mental symptoms (1–4). Approximately 70% of individuals with FM have cognitive dysfunction, known as "fibrofog" (3–5), which contributes to negative health perceptions and difficulty maintaining relationships, working, communicating, driving, organizing, and initiating activities of daily life (3–5). Despite growing evidence that FM is also associated with objective dysfunction across multiple cognitive domains (6,7), the totality of the evidence for impaired cognitive functioning in FM is equivocal, with a number of studies showing no difference or limited/focal differences in cognitive impairment between people with and without FM (8–17).

A gap exists in our knowledge of fibrofog and objective cognitive functioning where it matters most, in the everyday lives of people with FM. Research to date has relied on cross-sectional designs and standardized neuropsychologic tests, in a clinical environment, at a single visit. The controlled, artificial nature of this testing environment is fundamentally different from the real-world environment in which people perform cognitively demanding

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SIGNIFICANCE & INNOVATIONS

- This study investigates within-day fluctuations in subjective and objective cognitive function in the lives of individuals with fibromyalgia (FM) compared to a non-FM group.
- At baseline, the FM group showed moderate performance deficits and reported moderately worse cognitive function than the non-FM group; the groups were similar with regard to the correlation between subjective and objective measures of cognitive function.
- On ambulatory assessment, the FM group had poorer subjective cognitive function and objective working memory but not worse processing speed compared to the non-FM group.
- For both groups, momentary changes in processing speed, but not working memory, were associated with subjective reports of cognitive function.

tasks (18,19); consequently, these studies lack ecological validity, and their relationship to performance in the real world remains an open question (19,20). The snapshot of cognitive function from cross-sectional neuropsychologic studies is further limited because it fails to capture intraindividual variations in cognitive function (21,22). Variability in cognitive function in FM is important because fluctuating cognitive performance may itself be an indicator of poor cognition (23,24) and of vulnerability to future cognitive declines (25,26). Examining the variability of cognition within an individual may also provide new insights into the association between subjective (perceived) and objective (performance-based) cognitive dysfunction in FM.

A number of studies have demonstrated a discrepancy between subjective and objective cognitive functioning in FM (16,27,28), with depressed mood, alertness/hypersensitivity to fibrofog, and fatigue implicated as contributing factors to the disconnect. We lack insight about whether these findings of poor correlation between subjective and objective cognition at a between-person level are different between those individuals with and without FM, and whether this lack of correlation is also seen in daily life as difficulty accurately perceiving small moment-to-moment fluctuations in objective cognitive functioning in FM.

The goal of this study was to use ambulatory assessment methods to examine subjective and objective cognitive functioning in adults with FM and matched controls without FM in daily life. We compared the groups in terms of levels of cognitive functioning (subjective and objective processing speed and working memory) and association between subjective and objective cognitive functioning. We expected the FM group to show lower levels of subjective and objective cognitive functioning on both baseline and ambulatory measures. However, we expected no group differences in terms of the correspondence of subjective and objective cognitive functioning for either baseline or ambulatory data.

MATERIALS AND METHODS

Participants. Volunteers were eligible if they were age ≥18 years and able to fluently converse and read (6th grade level) in English. Volunteers were excluded if they had: 1) a comorbid neurologic disorder, a learning disorder, or cognitive impairment; 2) current alcohol or recreational drug dependence or prolonged (≥5 years) history of substance dependence; 3) visual or hearing impairment that would preclude cognitive testing; 4) diagnosis of untreated obstructive sleep apnea; or 5) atypical sleep/wake pattern (e.g., night-shift workers). Participants with FM fulfilled the 2016 American College of Rheumatology survey criteria (29); participants in the control group did not meet the criteria for FM and were matched to already-enrolled participants with FM based on sex, age, and education.

Study procedures. Prior to initiation of study activities, the Medical Institutional Review Board at the University of Michigan approved all study procedures. Participants were recruited from the University of Michigan through existing patient registries, community groups, placement of fliers in health centers and community settings, and advertisement on a university-based recruitment website (www.UMHealthresearch.org). Volunteers were screened for eligibility over the phone and provided written informed consent prior to beginning study activities. Data were collected between January and August, 2018.

Participation in this study involved an ~90-minute baseline visit followed by an 8-day home monitoring period (i.e., a 1-day run-in period followed by 7 days of data collection). At the baseline visit, enrolled participants completed a battery of self-report measures and standardized cognitive testing and were given data collection devices. At the conclusion of the home monitoring period, participants returned the devices via a postage-paid return box to the laboratory for data processing. Participants were compensated up to $175 for full completion of the study.

Participants were issued a ZTE Axon 7 mini smartphone, with a 5.2" display (1,080 × 1,920 pixels) and programmed with a customized study-specific app to administer ecological momentary assessment (EMA) measures and ambulatory cognitive tests. Participants were instructed to initiate the first of the 5 daily EMA and cognitive testing sessions upon waking. For the following 4 sessions, the smartphone was programmed to play an audible alert to prompt the respondent to complete EMA and cognitive assessments; alerts were programmed on a quasi-random schedule based on each person's typical waking time, with scheduled intervals between prompts ranging between 3 and 4.5 hours (18).

Measures. *Baseline self-report measures.* Participants completed surveys of demographics and medications and validated symptom surveys. The Multidimensional Inventory of Subjective Cognitive Impairment (MISCI) (30) consists of 10

items that assess cognitive functioning, rated on 2 scales ranging from 1 (not at all/never) to 5 (very much/very often), summed and converted to a T score metric (mean ± SD 50 ± 10); higher scores indicate better functioning. Pain was assessed with the Patient-Reported Outcomes Measurement Information System (PROMIS) pain intensity 3a short form, which assesses worst and average pain in the past 7 days (1 = no pain to 5 = very severe) and current level of pain (1 = no pain to 5 = very severe). Scores were summed and converted to a T score metric (mean ± SD 50 ± 10); higher scores indicate more pain. Depressive symptoms were measured with the Patient Health Questionnaire 8 (31), which assesses the frequency of 8 depressive symptoms in the past 2 weeks. Scores range from 0 to 24; higher scores indicate greater depressive symptomatology. Fatigue was assessed with a 4-item short form from the PROMIS fatigue item bank (32); scores are on a T score metric with a mean ± SD of 50 ± 10. Higher scores are indicative of higher fatigue.

Baseline cognitive tests. Four NIH Toolbox (33) cognitive tests were administered via the NIH Toolbox iPad app (34). The flanker task is a measure of attention and inhibitory control that requires participants to focus on a given stimulus while inhibiting attention stimuli flanking the target. The list sorting task is a test of working memory where participants recall and sequence stimuli presented both orally and visually. The dimensional change card sort is a test of cognitive flexibility and attention where pictures are presented varying by shape and color; the target dimension to be used for sorting (shape/color) is indicated by a cue word on the screen. The pattern comparison task is a measure of processing speed where participants are given 85 seconds to respond to as many stimuli as possible, discerning whether 2 simple pictures are identical or not. The NIH Toolbox provides a fully corrected T score for each test (mean ± SD 50 ± 10) corrected for age, education, sex, and race/ethnicity. Higher scores indicate better functioning.

Ambulatory assessments. A study-specific smart phone app was programmed to administer EMA measures and cognitive tests in a single assessment/testing session.

EMA. Subjective cognitive functioning was assessed with 2 items from the PROMIS applied general concerns (35) item bank, adapted for momentary assessment. The items "How slow is your thinking right now?" rated on a scale of 0–100 (where 0 = my thinking is very fast, and 100 = my thinking is very slow) and "How foggy is your thinking right now?" rated on a scale of 0–100 (where 0 = my thinking is very clear, and 100 = my thinking is very foggy) were averaged to produce an aggregate score where higher scores indicate worse subjective cognitive functioning. Cronbach's $\alpha = 0.95$, indicating excellent internal consistency.

Ambulatory objective cognitive tests. Two brief, valid, and reliable cognitive tests (18) were administered via the study-specific smart phone app following administration of EMAs.

Symbol search test. The symbol search was a test of processing speed, where participants saw a row of 4 symbol pairs at the top of the screen and 2 symbol pairs at the bottom of the screen. Participants decided, as quickly as possible, which symbol pair at the bottom matched a symbol pair at the top and selected the matching pair by touching their selection. Seventy-five percent of the trials contained a lure stimulus, meaning that 1 of the 2 symbols on a not-matching pair matched 1 of the symbols at the top (but the pair itself did not match). Stimuli were presented until a response was provided. Accuracy and reaction time (milliseconds) were recorded. Sixteen trials were administered per testing session. Two variables were calculated for sessions where accuracy was ≥70%: the average reaction time and SD (variability) in reaction time per session.

Symbol search session accuracy was used to assess participant effort in completing the test. Rote responding (i.e., indiscriminate selection of responses with little or no effort) would be consistent with accuracy rates of ~50%. Intentional poor performance (faking bad) would likewise be expected to correspond with low accuracy and could be expected to play a role in cases where accuracy was <50%. Accuracy of <70% was used as a conservative cut point to indicate poor effort; this cut point is consistent with the procedures used in the study to validate these measures (18).

Dot memory test. The dot memory was a test of working memory. Each trial consisted of 3 phases: encoding, distraction, and retrieval. During the encoding phase, the participant was asked to remember the location of 3 red dots appearing on a 5 × 5 square grid. After 3-seconds, the grid was removed and the distraction phase began, during which the participant was required to touch the Fs in an array of Es. After the distraction task, an empty 5 × 5 square grid was presented, and the participant had to place the red dots (by touching the empty squares) in the correct locations. Participants pressed "Done" when finished. Four test trials were administered each session. Euclidian distance, or the collective distance of the 3 dots from their correct locations (total error), was calculated. Three variables were calculated for dot memory: average, maximum, and SD of Euclidian distances across the 4 trials of each session.

Statistical analysis. Descriptive statistics for demographic and baseline measures were calculated. Independent samples *t*-tests were used to test group differences in baseline survey and cognitive test scores. Group differences in correlations between subjective and objective cognitive functioning were also tested (36). Graphs of subjective and objective cognitive functioning were plotted using mean scores at each within-day measurement time point collapsed across days and by group. Linear regression was used to determine whether group membership (FM/non-FM) predicted aggregate subjective or objective cognitive functioning scores across all days of study. Six objective functioning scores were investigated in separate analyses: 3 for processing speed

Table 1. Participant descriptive statistics by group*

	Total (n = 100)	FM (n = 50)	Non-FM (n = 50)
Age, years	45.1 ± 13.9	44.9 ± 13.9	45.2 ± 14.0
Age range, years	18–73	20–70	18–73
Female, no. (%)	88 (88)	44 (88)	44 (88)
Education, years	15.7 ± 2.0	15.7 ± 2.0	15.8 ± 2.0
Employment status, no. (%)			
Full-time	–	19 (38)	21 (42)
Part-time	–	10 (20)	17 (34)
Student	–	4 (8)	5 (10)
Unemployed	–	20 (40)	11 (22)
Race, no. (%)			
White	81 (81)	43 (86)	38 (76)
African American	13 (13)	5 (10)	8 (16)
Biracial/multiracial	3 (3)	2 (4)	1 (2)
Asian	3 (3)	0 (0)	3 (6)
Medication categories, no. (%)			
Opioid	–	16 (32)	1 (2)
Selective serotonin reuptake inhibitors	–	21 (42)	9 (18)
Tricyclic antidepressant	–	5 (10)	0 (0)
Pregabalin/gabapentin	–	8 (1)	2 (4)
Benzodiazepine	–	9 (18)	2 (4)
Sleep aid	–	13 (26)	0 (0)
Symptoms			
PROMIS pain intensity T score	45.0 ± 11.4	54.3 ± 6.1	35.6 ± 6.8
PROMIS fatigue experience T score	55.0 ± 13.8	65.9 ± 7.0	44.1 ± 9.5
Patient Health Questionnaire 8 (total score)	6.2 ± 5.9	10.6 ± 5.2	1.8 ± 2.1

* Values are the mean ± SD unless indicated otherwise. Percentages may total to >100 because participants could select >1 category. FM = fibromyalgia; PROMIS = Patient-Reported Outcomes Measurement Information System.

(mean, median, and SD of response times; symbol search test), and 3 for working memory (mean, maximum, and SD of the error scores; dot memory test). The first day of at-home data collection was excluded as a training day. To account for practice-related improvements in performance on ambulatory cognitive tests, models were adjusted for session number (a continuous variable that reflected the number of times the participant had completed the cognitive tasks). To investigate associations between momentary changes in subjective and objective cognitive functioning, person-centered objective cognitive functioning variables (reflecting momentary deviations from the participant's mean for the variable of interest) were included in separate multilevel models, with subjective cognitive functioning as the outcome, adjusted for session number (i.e., possible practice effects); in a final model, an interaction term between the objective cognitive functioning variable and group was used to test for group differences. Analyses were performed using Stata software, version 15. For significance tests, a *P* value of less than 0.05 was used as the threshold to determine statistical significance.

RESULTS

A total of 100 participants (50 FM, 50 non-FM) enrolled and provided data. The sample was mostly female and white, with an average age of 45 years; the FM group had a significantly higher rate of unemployed (χ^2[1 df] = 5.88, *P* = 0.02) (n = 100) (Table 1). Participants were generally adherent to the data collection protocol, providing data for an average of 90.9% of possible assessment sessions; the FM group had, on average, 91.2% complete data and the non-FM group 90.5%.

Table 2. Baseline cognitive tests group comparisons*

Measure of cognitive function	FM (n = 50)	Non-FM (n = 50)	*t*-test	*P*
MISCI	45.54 ± 2.64	54.04 ± 5.57	–11.80	<0.001
NIH Toolbox cognitive tests				
Flanker test	39.98 ± 9.50	43.78 ± 8.17	–2.14	0.03
List sorting task	49.34 ± 10.66	53.18 ± 8.32	–2.01	0.05
Dimensional change card sort test	46.38 ± 11.94	54.76 ± 13.20	–3.33	<0.01
Pattern comparison task	49.76 ± 16.21	57.36 ± 14.44	–2.47	0.02

* Values are the mean ± SD unless indicated otherwise. FM = fibromyalgia; MISCI = Multidimensional Inventory of Subjective Cognitive Impairment.

Table 3. Aggregate ecological momentary assessment (EMA) cognitive functioning variables*

Measure of cognitive function	FM (n = 50)	Non-FM (n = 50)	Regression analysis, mean difference (95% CI)	*P*
EMA of self-reported cognitive dysfunction, average/ aggregate	48.78 ± 16.69	17.31 ± 14.89	–31.47 (–37.75, –25.20)	<0.001
Processing speed: symbol search task, msec				
Mean response time	2,444.19 ± 752.39	2,256.60 ± 612.34	–187.59 (–459.84, 84.66)	0.18
Median response time	2,255.32 ± 715.52	2,078.34 ± 566.37	–176.97 (–433.08, 79.13)	0.17
SD of response times	1,028.00 ± 344.84	916.85 ± 323.94	–111.14 (–243.92, 21.64)	0.10
Working memory: dot memory task, Euclidean distance				
Mean error score	1.56 ± 0.88	1.04 ± 0.70	–0.52 (–0.84, –0.20)	0.002
Maximum error score	2.97 ± 1.08	2.26 ± 1.09	–0.71 (–1.14, –0.28)	0.001
SD of error score	1.18 ± 0.31	0.97 ± 0.39	–0.21 (–0.35, –0.07)	0.003

* Reference: fibromyalgia (FM) group. Values are the mean ± SD unless indicated otherwise. 95% CI = 95% confidence interval.

Group comparisons of baseline measures. The FM group reported significantly worse scores on subjective cognition and on measures of depressed mood, pain, and fatigue, and demonstrated poorer objective cognitive function on NIH Toolbox tests; however, differences on cognitive tests were <1 SD (Tables 1 and 2). The FM group reported higher levels of taking medications that could affect cognitive functioning; chi-square tests indicated significant group differences across all 6 medication categories listed (all $P < 0.05$) (Table 1).

Correlations between baseline subjective and objective cognitive function. The groups did not differ in terms of the correlations between subjective (MISCI scores) and objective cognition on the NIH Toolbox tests ($P > 0.06$ for all tests of group differences). For both groups, higher subjective cognitive functioning was correlated with better objective cognitive performance on all NIH Toolbox tests, except for the list sorting task, which showed no significant correlation with the MISCI in either group.

Effort on ambulatory cognitive testing. Accuracy on the symbol search task suggested good effort for both groups. Accuracy was >70% for 3,688 of 3,781 sessions (98.8%). The groups did not differ in terms of accuracy rates. For the FM group, accuracy was >70% for 1,784 of 1,813 sessions (98.4%, range 43.75–100.00%, median 100.00, mean ± SD 95.81 ± 6.83). For the non-FM group, accuracy was >70% for 1,904 of 1,918 sessions (99.2%, range 18.75–100.00%, median 100.00, mean ± SD 95.79 ± 6.32). Sixteen individuals, 8 within each subgroup, were identified as having had at least 1 session with <70% accuracy. Of these, 4 participants (n = 3 FM, n = 1 non-FM) had multiple sessions with low accuracy (range 5–12 sessions) and were identified as possible cases of low effort. No reaction time variables were calculated for low-accuracy sessions.

Sensitivity analyses, excluding the 4 participants who demonstrated repeated low accuracy/effort, were conducted for all ambulatory cognition analyses. The results with and without these 4 people did not change the magnitude or significance of any results. Therefore, results for the full sample are reported.

Aggregate ambulatory cognitive functioning scores. The FM group had poorer mean aggregate subjective cognitive functioning and poorer working memory (dot memory test mean error score, maximum error score, and SDs of the error scores; all $P < 0.01$). Although the FM group had, on average, slower processing speed (symbol search), the difference compared to the non-FM group was not statistically significant (Table 3). SD variables for reaction time (symbol search) and working memory (dot memory) reflect intraindividual variability in objective performance on these 2 cognitive tests (Table 3). While the FM group exhibited higher within-person variability, in absolute terms, for both reaction time and working memory, this group difference was statistically significant for working memory only. Plots of mean subjective and select objective cognitive functioning scores at each daily time point, by group, are shown in Figures 1 and 2.

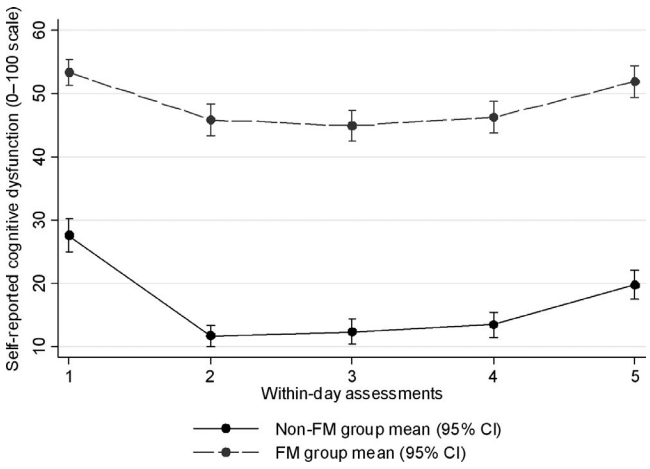

Figure 1. Plots of means for self-reported cognitive dysfunction by group at each within-day time point. FM = fibromyalgia; 95% CI = 95% confidence interval.

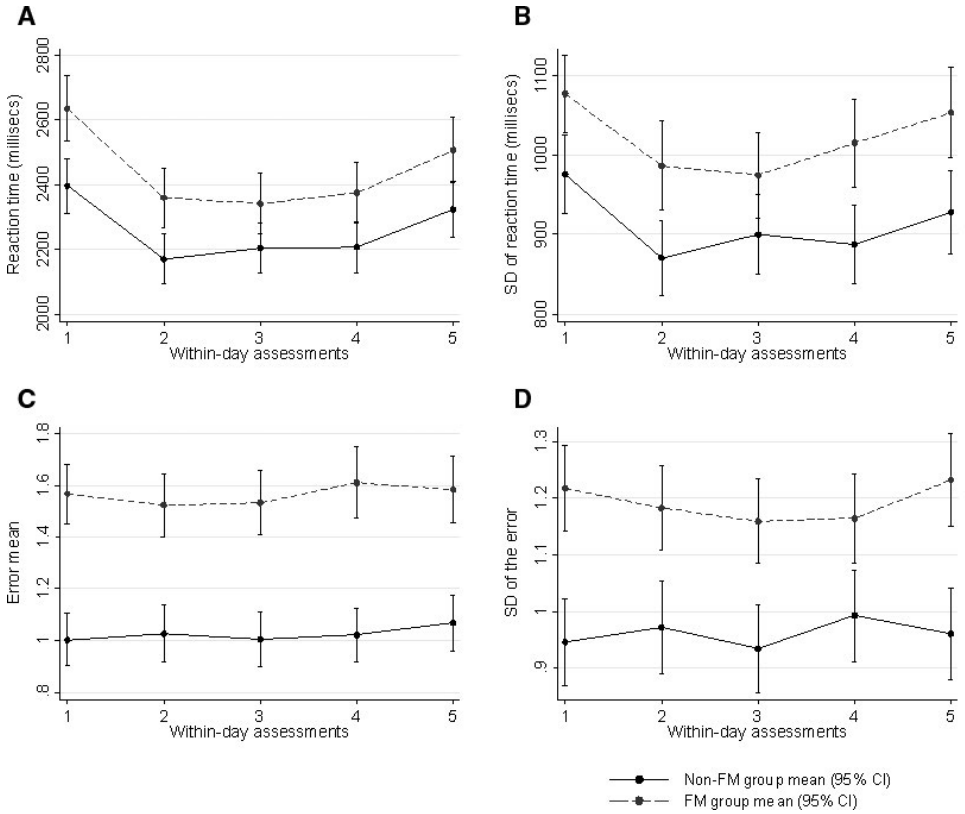

Figure 2. Plots of means for objectively measured cognitive function by group at each within-day time point. **A**, Symbol search mean response time; **B**, Symbol search SD of response time; **C**, Dot memory task mean error; **D**, Dot memory task SD of the error. FM = fibromyalgia; 95% CI = 95% confidence interval.

Associations between within-person subjective and objective cognitive functioning. Irrespective of group membership and practice effects, significant associations were observed between within-person momentary changes in response time (mean, median, and SD of response times) and subjective cognitive functioning. In contrast, there were no significant associations between momentary changes in working memory (mean, maximum, SD of error for the session) and subjective cognitive functioning (Table 4). Analyses that tested the interaction between objective test performance and group membership in predicting subjective cognitive function showed no evidence of a group effect on the association between any objective cognition variable and subjective cognitive function (all $P > 0.16$).

DISCUSSION

This study provides initial evidence of the characteristics of subjective ("fibrofog") and objective cognitive dysfunction in the daily lives of individuals with FM. Prior to examining cognitive functioning in real-world environments, we conducted a series of tests of subjective and objective cognitive functioning in the laboratory using a standardized battery of measures. The FM group reported worse cognitive function compared to the non-FM group, with subsample scores for FM approaching 1 SD lower than scores for the non-FM group. Consistent with prior research showing worse performance on standardized neurocognitive testing in FM, the FM group demonstrated worse attention (flanker and dimensional card sort tests), working memory (list sorting), and processing speed (pattern comparison) compared to the non-FM group; however, the between-group differences in test performance were modest (<1 SD). Furthermore, with the exception of scores on the flanker task, which were <1 SD below the normative mean, the FM group was within one-half SD of the normative sample mean of 50. In sum, analyses of baseline data showed that on standard laboratory-based cognitive tests and surveys of cognitive function, the FM group showed moderate performance deficits and reported moderately worse cognitive dysfunction. The FM group reported far more subjective cognitive difficulties compared to those individuals without FM, but findings that the FM group did not differ in terms of correlation between subjective and objective measures suggest that these complaints were not out of proportion to the cognitive deficits that the FM group demonstrated on baseline tests.

In terms of real-world ambulatory cognitive functioning, those individuals with FM demonstrated greater subjective cognitive dysfunction and poorer objective working memory, but not significantly worse processing speed, compared to individuals without FM. The lack of processing speed impairment in the FM group is in contrast to previous studies showing slower cognitive

Table 4. The association between within-person variation in objective cognitive function and momentary self-reported cognitive function (criterion variable) adjusted for group*

	Effect estimate	SE (95% CI)	*P*
Within-person variation in processing speed			
Symbol search task mean response time			
Intercept	48.10	2.43 (43.33, 52.87)	<0.001
Session number	0.03	0.04 (–0.05, 0.12)	0.43
Person-centered mean response time	0.006	0.001 (0.004, 0.007)	<0.001
Group	–31.31	3.15 (–37.48, –25.13)	<0.001
Symbol search task median response time			
Intercept	48.08	2.44 (43.30, 52.86)	<0.001
Session number	0.04	0.04 (–0.05, 0.12)	0.42
Person-centered median response time	0.006	0.001 (0.004, 0.008)	<0.001
Group	–31.31	3.15 (–37.49, –25.13)	<0.001
Symbol search task SD of response times			
Intercept	49.13	2.41 (44.41, 53.85)	<0.001
Session number	–0.03	0.04 (–0.11, 0.05)	0.51
Person-centered SD of response times	0.003	0.001 (0.002, 0.005)	<0.001
Group	–31.32	3.15 (–37.49, –25.14)	<0.001
Within-person variation in working memory			
Dot memory task mean error			
Intercept	49.50	2.41 (44.77, 54.22)	<0.001
Session number	–0.04	0.04 (–0.12, 0.04)	0.29
Person-centered mean error	–0.10	0.41 (–0.91, 0.71)	0.80
Group	–31.45	3.15 (–37.63, –25.28)	<0.001
Dot memory task maximum error			
Intercept	49.53	2.41 (44.80, 54.25)	<0.001
Session number	–0.05	0.04 (–0.12, 0.03)	0.27
Person-centered maximum error	–0.16	0.23 (–0.61, 0.28)	0.47
Group	–31.46	3.15 (–37.63, –25.28)	<0.001
Dot memory task SD of errors			
Intercept	49.53	2.41 (44.80, 54.26)	<0.001
Session number	–0.05	0.04 (–0.12, 0.03)	0.27
Person-centered SD of errors	–0.48	0.48 (–1.41, 0.45)	0.31
Group	–31.46	3.15 (–37.63, –25.28)	<0.001

* Reference: fibromyalgia group. 95% CI = 95% confidence interval.

processing in FM (37–40). Partially consistent with expectations, the FM group also showed greater intraindividual variability in working memory, but not in processing speed, compared with controls. Given that the laboratory-based test of processing speed showed significant group differences, the finding that the real-world test of this domain did not reveal group differences was unexpected. Lack of group differences on this ambulatory test may be due to a number of factors that warrant further exploration. Perhaps the ambulatory reaction time task used in this study is not adequately sensitive to actual group differences in processing speed; processing speed is a relatively basic, lower-order cognitive domain that underlies and mediates higher-order cognitive functions, such as executive functioning and memory (41,42). Therefore, deficits in processing speed in FM may be relatively modest compared with FM-related deficits in higher-order cognitive domains. This possibility is consistent with findings from a recent meta-analysis (6) showing that a specific aspect of executive functioning, inhibitory control, showed the largest effect size between individuals with FM and healthy controls, whereas processing speed showed a relatively smaller effect (6). Like the results from these meta-analyses, data from the current study suggest likely specificity in cognitive deficits in FM. Another possibility is that the ambulatory symbol search testing sessions may not have been challenging or lengthy enough to be sensitive to FM-related deficits. For this and other unidentified reasons, perhaps group differences in processing speed only emerge in the controlled environment of the laboratory and not in real-world settings.

Findings for focal deficits (worse working memory but not worse processing speed) for the FM subgroup, combined with comparable symbol search accuracy rates for the 2 groups, do not suggest that people with FM are demonstrating poor test motivation, faking bad, or global impairment. Previous studies have shown evidence of poor effort on tests among people with FM seeking disability benefits (43). However, even in studies that have found evidence of high rates of poor effort on cognitive testing in FM, effort did not totally explain dyscognition (44) and was not found at a higher rate in FM compared to other chronic pain conditions (16). Nevertheless, other studies have found no evidence for poor effort in FM (10,45,46) or for even greater achievement motivation in those with FM compared to age-matched controls (47).

Consistent with findings for baseline data, the association of subjective and objective cognitive functioning in daily life was not significantly different for those individuals with FM compared to those without FM. For both groups, only fluctuations in processing speed, but not working memory, were significantly related to concurrent ratings of subjective cognitive functioning, such that times of worse than usual reaction time were associated with lower subjective cognitive clarity and speed. Perhaps the lack of an association between working memory and subjective cognitive dysfunction is due to the fact that perceived memory ability was not assessed in the EMA items, which assessed cognitive clarity and speed. The finding that the groups were similar in terms of moment-to-moment correspondence between reaction time and subjective cognition does not support perceptual hypersensitivity to or perceptual exaggerations of fluctuations in objective cognitive performance in individuals with FM.

Although this study represents a crucial step in improving the ecological validity of cognitive assessment of fibrofog by assessing performance in the lived environment, the tests did not assess performance of real-world cognitive tasks. We assessed a relatively limited number of cognitive domains; perhaps larger group differences would emerge on tests of other domains (e.g., executive functioning) (6). The study did not include a standardized assessment of effort on baseline cognitive tests, so whether motivation played a role in the findings is not clear; however, there were low rates of poor effort on ambulatory tests of cognition, and removal of individuals who demonstrated occasional poor effort did not alter results. Although data on employment status were collected, we did not assess disability status and therefore cannot comment on its impact on performance.

In this first ambulatory study of cognitive function in FM, we aimed to examine how people with FM differ from individuals without FM and without significant symptoms (e.g., pain, fatigue); future studies that compare individuals with FM to individuals without FM but with chronic pain and fatigue would provide additional, crucial insights into the characteristics and mechanisms of fibrofog. Such comparisons are critical to understanding which aspects of fibrofog are related to having chronic pain (generally) and which are unique to FM. FM symptoms are observed on a spectrum, often referred to as fibromyalgianess (48–50); thus, FM/non-FM dichotomies such as the one considered here essentially mask both within-group diversity in overall fibromyalgianess and the overlap between groups in terms of the distribution of specific symptoms (e.g., fatigue). The association between cognitive functioning and both fibromyalgianess and specific symptom burden profiles warrants examination in larger and more diverse samples. Our aim was to examine and compare subjective and objective cognitive functioning in adults with and without FM. Accordingly, we did not adjust for distinguishing symptoms of FM in our statistical models (e.g., pain, fatigue, depression). However, future analyses of these data will explore the interplay and impact of hallmark FM symptoms on daily cognitive function.

AUTHOR CONTRIBUTIONS

All authors were involved in drafting the article or revising it critically for important intellectual content, and all authors approved the final version to be submitted for publication. Dr. Kratz had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study conception and design. Kratz, Sliwinski, Clauw, Williams.

Acquisition of data. Kratz.

Analysis and interpretation of data. Kratz, Whibley, Kim, Sliwinski, Clauw, Williams.

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