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Fibrofog in daily life: An examination of ambulatory subjective and objective cognitive function in fibromyalgia

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Abstract

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 aim of this study is to explore levels of subjective and objective cognitive functioning and the association between subjective and objective aspects of cognition in persons with and without FM in the lived environment.

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

Results: On baseline objective measures, the FM group demonstrated poorer cognitive functioning across three NIH Toolbox tests. There were no strong correlations between subjective and objective cognitive functioning in both the FM and control group. 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 lab-based and ambulatory subjective and objective cognitive function for those with FM compared to those without FM. Similar associations between measures of subjective and objective cognitive functioning for the groups suggest that people with FM are not overstating cognitive difficulties. Future research examining contributors to ambulatory fibrofog is warranted.

Key words: fibromyalgia, cognitive dysfunction, fibrofog, ambulatory assessment, working memory, processing speed

Significance and Innovations

- This study investigates within-day fluctuations in subjective and objective cognitive function in the lives of people 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.

Introduction

Approximately 5 million adults in the United States 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 endorse cognitive dsyfunction, 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).

One gap is 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 neuropsychological 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 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 neuropsychological studies is further limited because it fails to capture intra-individual 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 a person 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 with and without FM and whether this 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 is 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. But, we expected no group differences in terms of the correspondence of subjective and objective cognitive functioning, for either baseline or ambulatory data.

Materials & Methods

Participants

Volunteers were eligible if they were: 1) ≥18 years of age; and 2) able to fluently converse and read (6th grade level) in English. Volunteers were excluded if they endorsed: 1) comorbid neurological disorder, 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 (UM) approved all study procedures. Participants were recruited from the UM, 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 a ~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 lab 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 (1080 x 1920 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 five daily EMA and cognitive testing sessions upon waking. For the following four 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 3-4.5 hours(18).

Measures

Baseline self-report measures

Participants completed surveys of demographics, medications, and validated symptom surveys. The Multidimensional Inventory of Subjective Cognitive Impairment (MISCI)(30) consists of 10-items that assess cognitive functioning, rated on two scales ranging from 1=not at all/never to 5=very much/very often, summed and converted to a T-score metric (Mean=50, SD=10); higher scores indicate better functioning. Pain was assessed with the Patient Reported Outcome 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" scale) and current level of pain (1="no pain" to 5="very severe"). Scores were summed and converted to T-score metric (Mean=50, SD=10); higher scores indicate more pain. Depressive symptoms were measured with the Patient Health Questionnaire–8 (PHQ-8)(31) that assesses the frequency of 8 depressive symptoms in the past 2 weeks. Scores range from 0-24; 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=50 and SD=10. Higher scores are indicative of higher fatigue.

Baseline cognitive tests

Four National Institutes of Health (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 two simple pictures are identical or not. The NIH Toolbox provides a fully corrected T-score for each test (Mean=50, SD=10) corrected for age, education, gender, 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.

Ecological momentary assessment

Subjective cognitive functioning was assessed with two 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 to 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 to 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 is a test of processing speed, where participants saw a row of four symbol pairs at the top of the screen and two symbol pairs at the bottom of the screen.

Participants decided, as quickly as possible, which symbol pair at the bottom matches a symbol pair at the top and select the matching pair by touching their selection. Seventy-five percent of trials contained a lure stimulus, meaning that one of the two symbols on a not-matching pair matched one of the symbols at the top (but the pair 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%: average reaction time and standard deviation (variability) in reaction time per session.

Symbol Search session accuracy was used to assess participant effort in completing the test. Rote responding (i.e. indiscriminant selection of responses with little or no effort) would be consistent with accuracy rates of about 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 is consistent with the procedures used in the study to validate these measures (18).

Dot Memory Test

The Dot Memory is a test of working memory. Each trial consists of 3 phases: encoding, distraction, and retrieval. During the encoding phase, the participant is asked to remember the location of three red dots appearing on a 5X5 square grid. After 3-seconds, the grid is removed and the distraction phase begins, during which the participant is required to touch the F's in an array of E's. After the distraction task, an empty 5X5 square grid is presented and the participant must place the red dots (by touching the empty squares) in the correct locations. Participants press "Done" when finished. Four test trials are administered each session. Euclidian distance, or the collective distance of the three dots from their correct locations (total error), was calculated. Three variables were calculated for Dot Memory: Average, maximum, and standard deviation of Euclidian distances across the four trials of each session.

Data 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: three for processing speed (mean, median, and standard deviation of response times; Symbol Search test), and three for working memory (mean, maximum, and standard deviation 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 (Version 15, StataCorp, College Station, TX). For significance tests, a *p* value of less than 0.05 was used as the threshold to determine statistical significance.

Results

One hundred 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, N=100) =5.88, *p*=0.02; **Table 1**). Participants were generally compliant with 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%.

Group comparisons of baseline measures

The FM group reported significantly worse scores on subjective cognition, and measures of depressed mood, pain, and fatigue, and demonstrated poorer objective cognitive function on NIH Toolbox tests; however, differences on cognitive tests were <1SD (**Tables 1 and 2**). The FM group reported higher levels of taking medications that could affect cognitive functioning; chi-square tests indicate significant group differences across all six 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 test 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 3688/3781 (98.8%) of all sessions. The groups did not differ in terms of accuracy rates. For the FM group, accuracy was >70% for 1784/1813 (98.4%) of sessions (range=43.75-100.00%; Median=100.00, Mean=95.81, SD=6.83). For the non-FM Group, accuracy was >70% for 1904/1918 (99.2%) of sessions (range=18.75-100.00%; Median=100.00; Mean=95.79; SD=6.32). Sixteen individuals, 8 within each subgroup, were identified as having had at least one session with <70% accuracy. Of these, four 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 four participants who demonstrated repeated low accuracy/effort, were conducted for all ambulatory cognition analyses. The results with/without these four 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 standard deviations 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**). Standard deviation variables for reaction time (Symbol Search) and working memory (Dot Memory) reflect intra-individual variability in objective performance on these two 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 depicted in **Figures 1 and 2**.

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 standard deviation 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 those with FM. Prior to examining cognitive functioning *in vivo*, 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 1SD lower than scores for the non-FM group. Consistent with prior research demonstrating worse performance on standardized neurocognitive testing in FM, the FM group demonstrated worse attention (Flanker & 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 (<1SD). Furthermore, with the exception of scores on the Flanker task, which were <1SD below the normative mean, the FM group was within ½ SD of the normative sample mean of 50. In sum, analyses of baseline data show that on standard lab-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 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 they demonstrated on baseline tests.

In terms of real-world ambulatory cognitive functioning, those with FM demonstrated poorer subjective cognitive dysfunction and objective working memory, but not significantly worse processing speed, compared to those without FM. The lack of processing speed impairment in the FM group is in contrast to previous studies showing slower cognitive processing in FM (37-40). Partially consistent with expectations, the FM group also showed greater intra-individual variability in working memory, but not in processing speed, compared with controls. Given that the lab-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. Reasons for lack of group differences on this ambulatory test may be due to a number of factors that warrant further exploration. It may be that 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). As such, deficits in processing speed in FM may be relatively modest compared with FM-related deficits in higher order cognitive domains. This 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 people with FM and healthy controls, whereas processing speed showed a relatively smaller effect (6). Like the results from this 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, it may be that 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 two 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). But, 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). Still, 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 were not significantly different for those with compared to 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. It is plausible that 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 persons with FM.

Study Limitations

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; it may be that 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 it is not clear whether motivation played a role in the findings; 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 was 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 people with FM to people 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. Fibromyalgia symptoms are observed on a spectrum, often referred to as fibromyalgianess (48-50); as such, 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 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 this data will explore the interplay and impact of hallmark FM symptoms on daily cognitive function.

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Conflict of Interest.

The authors have no conflicts of interest to report.

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Figure Legend

Figure 1. Plots of means for self-reported cognitive dysfunction by group at each within-day time point.

Figure 2. Plots of means for objectively measured cognitive function by group at each within-day time point.

Figure 1.

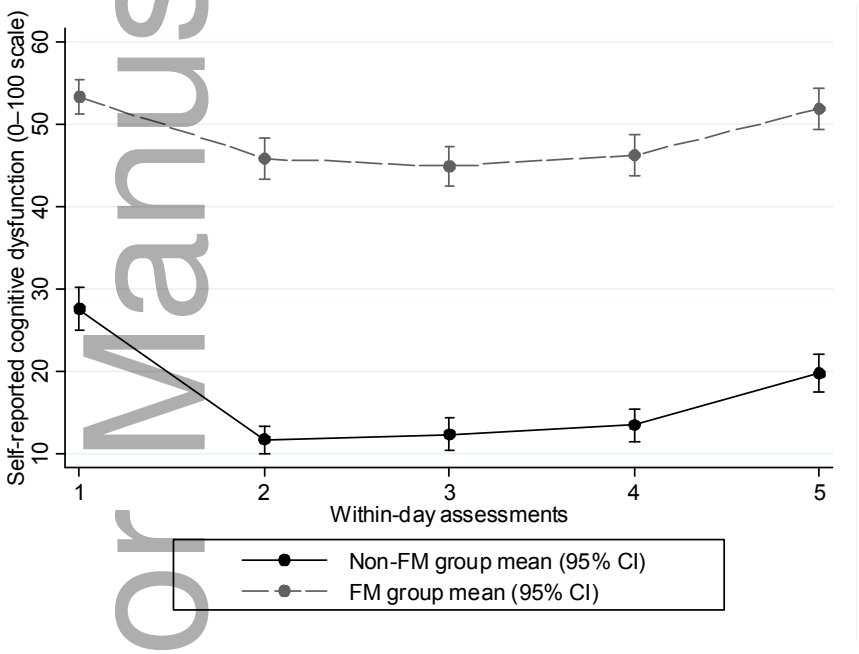
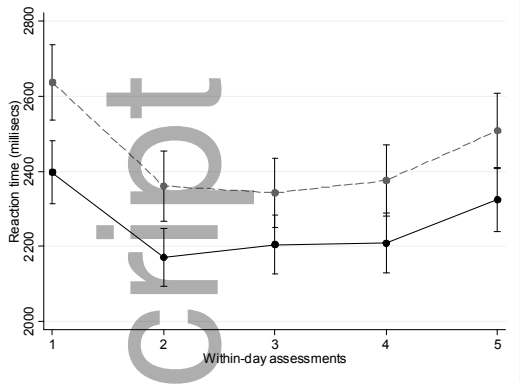
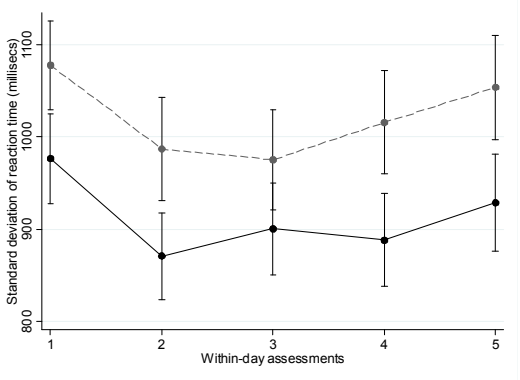


Figure 2.

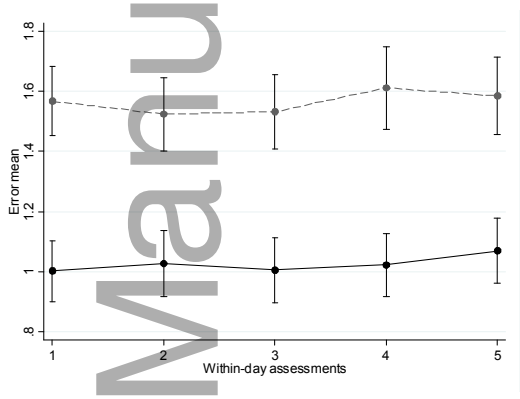
a. Symbol search mean processing speed



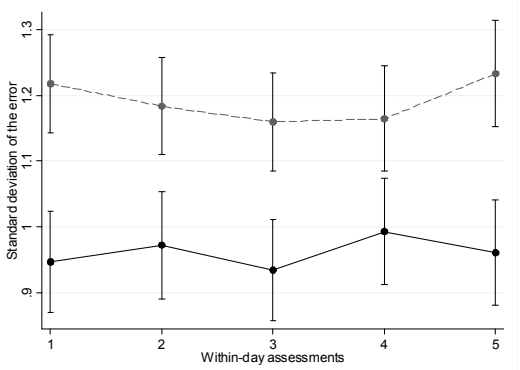
b. Symbol search SD of processing speed



c. Dot memory task mean error



d. Dot memory task SD of the error



SD: standard deviation

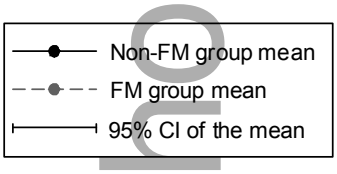


Table 1. Participant descriptive statistics by group

	Total N=100	**FM N=50**	**Non FM N=50**
Age, years			
Mean (SD)	45.1 (13.9)	44.9 (13.9)	45.2 (14.0)
Range	18–73	20–70	18–73
Female, N (%)	88 (88%)	44 (88%)	44 (88%)

Education			
Years, mean (SD)	15.7 (2.0)	15.7 (2.0)	15.8 (2.0)
Employment Status*			
Full-time		19 (38)	21 (42)
Part-time		10 (20)	17 (34)
Student		4 (8)	5 (10)
Unemployed		20 (40)	11 (22)
Race			
White	81 (81%)	43 (86%)	38 (76%)
Black	13 (13%)	5 (10%)	8 (16%)
Bi/multi-racial	3 (3%)	2 (4%)	1 (2%)
Asian	3 (3%)	0 (0%)	3 (6%)
Medication Categories, N (%)			
Opioid		16 (32%)	1 (2%)
SSRI		21 (42%)	9 (18%)
Tricyclic antidepressant		5 (10%)	0 (0%)
Pregabalin/gabapentin		8 (16%)	2 (4%)
Benzodiazepine		9 (18%)	2 (4%)
Sleep Aid		13 (26%)	0 (0%)
Symptoms (mean, SD)			
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)
Note. Percentages may total to >100 because participants could select more than one category. SSRI= Selective serotonin reuptake inhibitors			

Table 2. Baseline cognitive tests group comparisons

Measure of cognitive function	FM	Non FM	t	p

	N=50	N=50		
Multidimensional Inventory of Subjective Cognitive Impairment (MISCI) (*mean, SD*)	45.54 (2.64)	54.04 (5.57)	-11.80	<0.001
NIH-Toolbox Cognitive Tests (mean, SD)				
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

Table 3. Aggregate EMA cognitive functioning variables

Measure of cognitive function	**FM N=50**	**Non FM N=50**	**Regression analysis†**
	Mean (SD)	**Mean (SD)**	**Mean difference (95% CI)**
Ecological momentary assessments of self-reported cognitive dysfunction			
Average/aggregate (mean, SD)	48.78 (16.69)	17.31 (14.89)	-31.47 (-37.75 to -25.20) p<0.001
Processing speed: Symbol search task (millisecs)			
Mean response time	2444.19 (752.39)	2256.60 (612.34)	-187.59 (-459.84 to 84.66) p=0.18
Median response time	2255.32 (715.52)	2078.34 (566.37)	-176.97 (-433.08 to 79.13) p=0.17
Standard deviation of response times	1028.00 (344.84)	916.85 (323.94)	-111.14 (-243.92 to 21.64) p=0.10
Working memory: Dot memory task (Euclidean distance)			
Mean error score	1.56 (0.88)	1.04 (0.70)	-0.52 (-0.84 to -0.20) p=0.002
Maximum error	2.97	2.26	-0.71 (-1.14 to -0.28)

score	(1.08)	(1.09)	p=0.001
Standard deviation of error score	1.18 (0.31)	0.97 (0.39)	-0.21 (-0.35 to -0.07) p=0.003

†Reference group: FM group

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
Within-person variation in processing speed: 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
Within-person variation in processing speed: symbol search task standard deviation 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

Within-person variation in working memory: 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
Within-person variation in working memory: dot memory task – standard deviation of errors				
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Session number	-0.05	0.04	-0.12, 0.03	0.27
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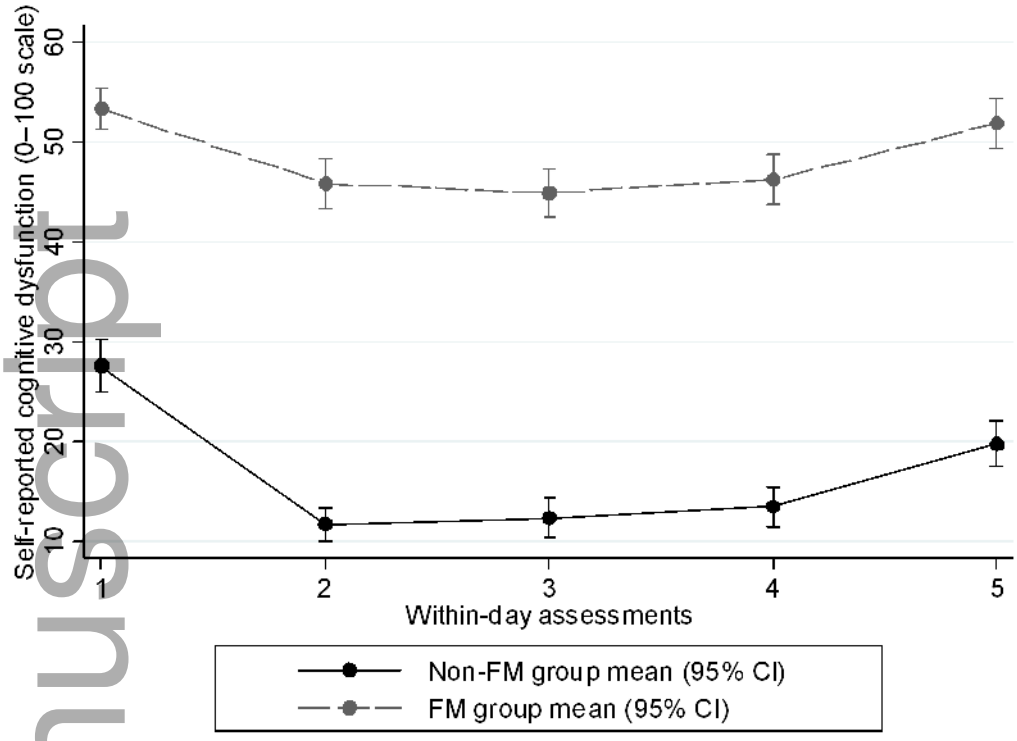

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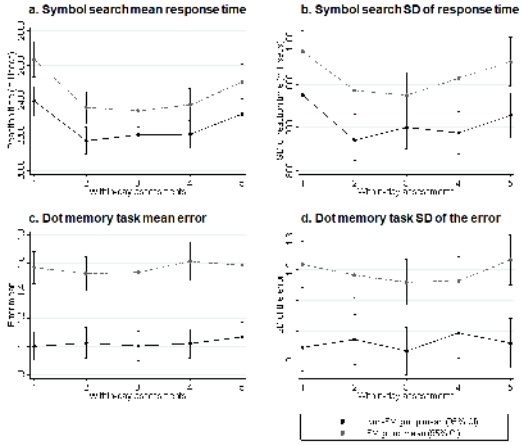

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