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Research Article

It's complicated: Executive functioning moderates impacts of daily busyness on everyday functioning in community-dwelling older adults

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Abstract

Objective: Research shows that cognitively healthy older adults with mild executive function (EF) weaknesses are vulnerable to the negative impacts of life complexity (or daily busyness) when performing instrumental activities of daily living (IADLs). However, past research assessed life complexity only at one timepoint, not capturing daily fluctuations. Importantly, fluctuations in busyness can themselves have deleterious impacts on functioning. This study extended past research by examining whether (1) *variability* in daily busyness would be more detrimental than *level* of busyness to performance of IADLs, and (2) EF assessed at home would moderate deleterious impact of busyness on IADLs. **Method:** Fifty-two community-dwelling older adults aged 60 to 95 completed daily IADL tasks and daily measures of EF and busyness via ecological momentary assessment, independently at home for 18 days. **Results:** (1) In a subset of participants with mild EF weaknesses, high *variability* in busyness across days was associated with fewer tasks completed *correctly*; and (2) across all participants (regardless of EF), high *levels* of daily busyness were associated with fewer tasks completed *on time*. **Conclusions:** Findings indicate that high variability in daily busyness, potentially reflecting a lack of daily routine, was associated with IADL errors among cognitively healthy older adults with mild EF weaknesses. Additionally, consistently high levels of busyness were associated with failures to complete tasks, or failures to complete them on time, regardless of EF. These results further support the Contextually Valid Executive Assessment (ConVExA) model, which posits that EF and contextual factors interact to predict functional outcomes.

Keywords: executive function; cognition; aging; daily functioning; Independent living; life complexity; busyness; routine

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Introduction

Executive functioning (EF) is a neurocognitive domain comprised of a set of higher-order processes that facilitate execution of purposeful and goal-directed actions (Lezak et al., 2012; Suchy, 2015). Because EF is needed for successful execution of instrumental activities of daily living (IADLs; Royall et al., 2007), performances on tests of EF are frequently used as predictors of functioning in daily life, with much research supporting such practice (Bell-McGinty et al., 2002; Marshall et al., 2011; Tomaszewski Farias et al., 2009). Nevertheless, traditional measures of EF have been criticized for having poor ecological validity (Burgess et al., 2006; Chaytor et al., 2006; Royall et al., 2004).

To improve the utility of EF assessment, numerous researchers have begun to develop more ecologically valid instruments (Hamera & Brown, 2000; Josman et al., 2009; Jovanovski, Zakzanis, Campbell, et al., 2012; Lalonde et al., 2013; Lamberts et al., 2010; Schmitter-Edgecombe et al., 2021), with the assumption that ecologically valid tests would represent a "silver bullet" that would dramatically improve predictions of patients' IADL capacities (Burgess et al., 2006). However, after some 30 years of such efforts, only a handful of such tests have been translated into clinical use (e.g., Wilson et al., 1996), and the superiority of such tests over traditional batteries has not been unequivocally demonstrated (e.g., Jansari et al., 2014; Jovanovski, Zakzanis, Campbell, et al., 2012; Jovanovski, Zakzanis, Ruttan, et al., 2012; Maeir et al., 2011; Rand et al., 2009; Robertson & Schmitter-Edgecombe, 2016; Spitoni et al., 2018). Indeed, recent research suggests that face validity (presumed to increase ecological validity) does not incrementally improve prediction of IADLs in daily life (Suchy et al., in press; Ziemnik & Suchy, 2019).

As an alternative to the "silver bullet" approach, we have advocated for the development of more ecological *applications* of existing EF tests, wherein the patients' individual contexts are more heavily weighted (Suchy, 2015, 2020, in press). To that end, we have proposed the Contextually Valid Executive Assessment model (ConVExA; Suchy, 2015; Suchy, Ziemnik, Niermeyer, et al., 2020), which posits that IADL performance is determined by an interplay between cognition and quantifiable contextual factors, with EF acting as both a mediator and a moderator. Specifically, some contextual factors have a detrimental *indirect* impact on IADLs via their direct negative impact on EF, whereas others impact IADLs *directly*, but only among individuals who are

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vulnerable to such impacts due to pre-existing EF weaknesses. Extensive research supports the mediation aspect of the ConVExA model, demonstrating that (a) EF is vulnerable to a variety of contextual factors, including nonrestorative sleep (e.g., Niermeyer & Suchy, 2020a; Tinajero et al., 2018), sleep deprivation (Lim & Dinges, 2010; Waters & Bucks, 2011), pain interference (Boselie et al., 2016; Buhle & Wager, 2010; Niermeyer & Suchy, 2020a), and engagement in burdensome emotion regulation (Franchow & Suchy, 2017; Niermeyer & Suchy, 2020a,b); and (b) such factors indirectly impact IADLs via contextually induced, temporary decrements in EF (Brothers & Suchy, 2022; Niermeyer & Suchy, 2020b; Suchy et al., 2019). In contrast to the fairly extensive research supporting the mediation aspect of the ConVExA model, thus far only one study has explicitly tested the moderation component of the model (Suchy et al., 2020).

This study (Suchy et al., 2020) demonstrated that high self-reported complexity[1] of participants' daily lives was associated with poorer medication management over the subsequent 8 weeks. Importantly, this impact was only present for a subset of participants whose EF scores were in the bottom 22% of the sample. Put differently, EF *moderated* the impact of life complexity on medication management. However, this study was limited in two important ways. First, it assessed EF in a single administration; given that EF fluctuates (McKinney et al., 2020; West et al., 2002), this single assessment potentially failed to capture typical EF levels across the eight weeks of the study. Second, complexity was also assessed only once (at baseline), thus making it unclear whether participants' *actual* daily life complexity across the following eight weeks corresponded to their baseline self-report. Relatedly, it was unclear whether the "active ingredient" in the association between life complexity and daily functioning was the *overall greater busyness* (i.e., a greater amount of time spent in activities) among people whose lives are complex, or whether it was the *variability*, or day-to-day fluctuations, in daily busyness (reflecting a lack of routine from day to day). This question is important given that fluctuations in some contextual factors may be more detrimental to functioning than stable, albeit high, levels of such factors (Brothers & Suchy, 2022).

The purpose of the present study was to address the limitations of prior research, with two specific goals. First, we examined whether daily life complexity, operationalized in this study as self-reported sense of busyness relative to a typical day, would incrementally predict daily IADLs beyond daily levels of EF, and, specifically, whether *variability* in daily busyness would be more detrimental than *average level* of busyness. This is an important question, as the distinction between level and variability in busyness would inform both future assessment methods and potential interventions. Second, as a test of the ConVExA model, we examined whether overall level of EF, averaged across 18 days, would moderate the impact of busyness on daily functioning. Answering this question addresses the issue of whether longitudinal assessment of EF at home has similar implications as office-based assessment. To these ends, we recruited older adults who completed a series of IADL tasks at home over 18 days, along with daily Ecological Momentary Assessment (EMA) of EF and busyness. Based on past research (Brothers & Suchy, 2022; Suchy et al., 2020; Tassoni et al., 2022), we predicted that fluctuations in self-reported busyness (deemed to reflect deviation from routine and greater life complexity overall) would be more detrimental to daily functioning than average levels of busyness, but that this effect would only hold for those with lower levels of average daily EF.

[1]Complexity was operationalized in Suchy et al. (2020) as engagement in a variety of *different* activities over the course of a typical week, assessed via detailed structured interview about vocational, avocational, social, homemaking, and caretaking activities in a typical week.

Table 1. Characteristics of the sample and descriptive statistics for dependent and independent variables

	Mean	SD	Minimum	Maximum
Age	69.33	6.40	60.00	95.00
Education	16.87	2.34	12.00	22.00
DRS-2 SS	11.60	2.23	6.00	16.00
DRS-2 Raw	139.50	3.48	129.00	144.00
GDS	3.85	3.60	0.00	14.00
Weekly Hours at Work[a]	1.93	2.21	0.00	8.54
DALIES total score	72.75	5.95	56.00	83.00
DALIES timeliness[b]	32.33	2.94	23.00	36.00
DALIES accuracy[c]	40.25	4.27	28.00	47.00
Busy-Mean	50.57	9.18	22.83	70.04
Busy-SD	17.67	6.77	1.06	33.55
EMA-EF	.00	.78	-2.53	1.49

Note. $n = 52$ for all variables except GDS ($n = 49$). Participants were primarily female (66%) and white (98% non-Hispanic white, 2% Hispanic white). *DRS*-2 = Dementia Rating Scale, 2nd edition; SS = age-corrected total scaled score; GDS = Geriatric Depression Scale; DAILIES = Daily Assessment of Independent Living and Executive Skills; EMA-EF = Ecological Momentary Assessment-Executive Functioning.
[a]13% of participants did not hold a formal job, 70% of participants worked fewer than 4 h a day, and 17% of participants worked between 4 and 8.54 h per day.
[b]Possible range of scores is 0 to 36. [c]Possible range of scores is 0 to 5.

Method

Participants

Participants were 52 older adults recruited as part of a prior study on contextual contributors to daily functioning (Brothers & Suchy, 2022). Data were obtained in compliance with the university IRB and Helsinki Declaration. Participants were recruited through the University of Utah's Center on Aging, Osher Lifelong Learning Institute, and a Senior Expo. Potential participants were eligible if they were at least 60 years old, lived independently, and had no self-reported history of dementia, mild cognitive impairment, or other significant neurological history (e.g., epilepsy, stroke). Participants were excluded if they had self-reported color-blindness, uncorrected hearing or visual impairments that would preclude task performance, or less than 8 years of education. Since this study focused on functioning of community-dwelling individuals who are deemed cognitively healthy, participants were only screened for gross cognitive limitations and were not adjudicated diagnostically. However, one participant was excluded from analyses due to extremely low scores (more than 2 SDs below expectation) on the memory subtest of a screening measure. Participants were primarily female (66%) and racially homogenous (98% non-Hispanic White, 2% Hispanic White). See Table 1 for additional sample characteristics.

Measures

Characterizing the sample

To characterize participants' general cognitive status, we used the Dementia Rating Scale-Second Edition (Jurica et al., 2001). To characterize levels of depressive symptoms, participants completed the 30-item version of the Geriatric Depression Scale (Yesavage, 1988).

Home-based IADLs

Home-based IADLs were assessed using the Daily Assessment of Independent Living and Executive Skills (DAILIES) protocol.

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Table 2. Participants' responses to DAILIES debriefing form

	% participant endorsement				
Debriefing item	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
DAILIES tasks reminded me of typical daily tasks	45.7	47.8	4.3	2.2	0
DAILIES tasks were as difficult as other daily tasks	19.6	47.8	23.9	8.7	0
I was able to fit DAILIES into my daily schedule	32.6	50.0	8.7	8.7	0

Note. $n = 52$.

The DAILIES, recently developed in our laboratory, is described in detail in Brothers & Suchy (2022). Briefly, participants completed tasks that resemble typical IADLs, six days a week for three weeks. The tasks span six IADL categories: (a) bill paying/finances, (b) looking up information on the internet, (c) password management, (d) shopping/running errands, (e) solving hypothetical daily life problems, and (f) communication. Each week, participants completed one task from each category, thus completing three different tasks from each category across the three weeks. Participants performed the tasks in a fixed order (i.e., same order for all participants), which was determined pseudo-randomly during instrument development. Participants were required to (a) provide evidence of task completion within specified timeframes that varied daily (to mimic typical daily demands, such as needing to call a doctor during their office hours), and (b) to communicate with the researchers via specific methods (email, telephone, or postal mail), which again varied daily (to mimic typical daily demands). Scoring comprised both timeliness (one point if the task was completed, and one point if the task was completed during the correct time window) and accuracy (one to seven points depending on task complexity). The sum of scores across all 18 tasks, referred to as *DAILIES* below, was used in analyses as the dependent (or outcome) variable, reflecting home-based IADL performance. Because no tasks are repeated, no practice effects are evidenced across the 18 days. As would be expected, the *DAILIES* has been found to correlate with clinical EF measures, and with EMA-EF performance (Suchy et al., in press).

EMA assessment of busyness

To assess daily busyness, participants completed a Qualtrics survey six days a week (between 7:00 PM and before going to bed) for three weeks concurrent with completion of the DAILIES. The survey included inquiries about various contextual factors, including a question: "Compared to your typical day, how busy[2] were you today overall?" Participants responded using a slider on a scale from zero (not busy at all) to 100 (much more busy than usual). The rationale for inquiring about a within-person comparison was that daily variability, or deviations from routine, were hypothesized to be more detrimental than overall busyness levels. Additionally, people differ in how they deem themselves to be busy relative to others, arguably making within-person comparisons more valid. The mean and standard deviation of participants' responses across the 18 days were used in analyses as average level of busyness and variability in busyness. These variables are referred to as "Busy-Mean" and "Busy-SD" below. Cronbach's alpha across the 18 days was .819.

[2]We did not define the word "busy," given that it is fairly uniformly interpreted by people as the degree to which one's time is filled with activities (Darrah, Freeman, & English-Lueck, 2007).

EMA assessment of EF

To assess daily levels of EF, participants completed two EF tasks, a Stroop-based task (Stroop, 1935) and a task resembling backward digit span, via the same Qualtrics survey described above. The Stroop task included names of common furniture items (baseline condition) and colors (inhibition condition) written in red, blue, or yellow ink. Below each word, participants selected from three options to identify which color of ink the word was written in. The baseline condition lasted 30 s and was followed by a 30-second inhibition condition. Total correct responses and errors were computed for each condition each day, then baseline scores were subtracted from inhibition scores to isolate inhibition. To place all days on the same metric and thereby control for any potential practice effect, we computed sample-based *z*-scores for each day. Means of these standardized variables across the 18 days were computed, and the two Stroop variables were averaged to arrive at a single Stroop score.

The backward digit span task was comprised of 12 number strings that increased in length by one digit every two trials (strings were three to eight digits long). Participants had a standard amount of time to view each string, adjusted for string length, and were then asked to type the digits in reverse order. The number of items correctly answered was recorded each day, *z*-scores for each day were generated to control for practice effects, and 18-day mean scores were computed. To calculate participants' overall EF performance, the Stroop and digit span overall *z*-score-based means were averaged to generate a single *EMA-EF* composite. Higher scores indicate better performance. Cronbach's alpha across the 18 days was .835.

Results

Preliminary analyses

Descriptives and score distributions

All variables were normally distributed (skewness ranging from −.638 to −.171), except for the DAILIES, which was slightly skewed (skewness = −1.31) due to two outliers. These outliers were Winsorized, bringing their values within 3 SDs of the mean, normalizing the distribution (skewness = −.99). See Table 1 for descriptive statistics.

DAILIES debriefing

After completing the 18 days of the DAILIES, participants filled out a debriefing form. As seen in Table 2, participants overwhelmingly felt the DAILIES tasks were similar to typical tasks they complete in daily life. Additionally, 91% of participants indicated that the DAILIES tasks took less than 15 min each day, with 9% indicating that tasks took 15 to 30 min.

Zero-order correlations and potential confounds

Zero-order correlations among dependent and independent variables and potential confounds (i.e., demographics, depression,

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Table 3. Zero-order correlations between the primary dependent and independent variables and sample characteristics

	DAILIES	EMA-EF	Busy MEAN	Busy-SD
Age	−.006	−.235	−.117	−.448**
Sex	−.054	−.047	.181	.435**
Education	.273*	−.063	−.065	−.138
DRS-2 Raw	−.030	.189	.027	−.001
GDS raw	.033	.017	−.073	.162
Weekly hours spent at work	−.024	−.210	.247	.218

Note. $n = 52$ for all variables except GDS ($n = 49$). Sex is coded male = 0, female = 1. DRS-2 = Dementia Rating Scale, 2nd edition – total raw score; GDS = Geriatric Depression Scale; DAILIES = Daily Assessment of Independent Living and Executive Skills; EMA-EF = Ecological Momentary Assessment-Executive Functioning.
*$p < .05$.
**$p < .01$.

Table 4. Hierarchical linear regressions predicting the DAILIES score

Model	Step	Predictors	R^2	R^2 Δ	F Δ	DF	p
1	1	Age, Education, Sex	.069	–	1.19	3,48	.324
	2	EMA-EF	.245	.176	10.97	1,47	.002
	3	Busy-Mean	.314	.069	4.61	1,46	.037
	4	Busy-SD	.315	.001	.072	1,45	.790
2	3	Busy-SD	.246	.001	.041	1,46	.840
	4	Busy-Mean	.315	.069	4.55	1,45	.038

Note. $n = 52$. DAILIES = Daily Assessment of Independent Living and Executive Skills; EMA-EF = Ecological Momentary Assessment-Executive Functioning.

cognitive status) are presented in Table 3. As seen in the table, age and sex correlated with Busy-SD, such that women reported more variability in busyness than men, whereas older individuals reported less variability than younger individuals. Additionally, education correlated with the DAILIES, such that more educated individuals performed better. Of note, the number of hours participants reported spending at work was not correlated with Busy-Mean or Busy-SD.

Principal analyses

Our first aim was to examine whether daily busyness would impact daily IADL performance beyond EF, and whether variability in busyness (i.e., Busy-SD) would be more detrimental to daily functioning than average levels of busyness (i.e., Busy-Mean). To this end, we conducted two hierarchical linear regressions, using the DAILIES as the dependent variable, and relevant covariates (age, education, and sex, per Table 3) as predictors in step 1, followed by EMA-EF in step 2. Additionally, Busy-Mean and Busy-SD were entered as predictors in steps 3 and 4, respectively, and then again in the reverse order (Busy-SD in step 3 and Busy-Mean in step 4), to parse out unique and overlapping variances. The results are presented in Table 4. As seen in the table, contrary to prediction, Busy-Mean emerged as a unique predictor beyond Busy-SD, which itself did not contribute to the model. The variance accounted for by the model was 32%.

Our second aim was to examine whether EF moderated the association between daily IADLs and daily busyness. To this end, we ran two general linear regressions in PROCESS macro v4.0 (bootstrap samples = 5000; Hayes, 2021) in SPSS, again using the DAILIES as the dependent variable, age, education, and sex as covariates, and EMA-EF, Busy-Mean, and Busy-SD as predictors. In the first regression, we specified EMA-EF as a moderator of Busy-Mean, and in the second regression we specified EMA-EF as a moderator of Busy-SD. The results are presented in Table 5. As seen in the table, EMA-EF and Busy-Mean continued to emerge as unique predictors in both analyses. Additionally, while EMA-EF did not moderate Busy-Mean, it did moderate Busy-SD, consistent with our prediction and with the ConVExA model. This moderation effect added about 10% of variance to the model (for a total of 42% of variance in the DAILIES accounted for by the full model). Johnson-Neyman regions of significance were identified and revealed that Busy-SD was associated with DAILIES performance for participants whose EMA-EF scores fell 0.96 SD below the mean, corresponding to the bottom 15.38% of the sample. Specifically, for those participants with lower EMA-EF, DAILIES performance decreased significantly as Busy-SD increased. In other words, high variability in busyness was associated with *lower* IADL performance, but only for participants with weaker EF. A second region of significance emerged for participants whose EMA-EF scores fell 1.12 SD above the mean, corresponding to the top 13.46% of the sample. For participants with higher EMA-EF, high variability in busyness was associated with *higher* IADL performance; however, there was a narrow range of variability in busyness among the high EMA-EF individuals, and the results in this subgroup were driven by only two individuals with lower DAILIES score, making the results for this second region of significance difficult to interpret. These moderation effects are depicted in Figure 1.

Table 5. General linear regressions predicting the DAILIES score

Model	Predictors	B	*Std. Error*	*Beta*	t	p
1	Constant	56.45	11.348	–	4.97	<.001
	Age	.078	.139	.084	.56	.577
	Education	.561	.349	.220	1.61	.115
	Sex	2.07	1.811	.167	1.14	.259
	EMA-EF	2.254	.971	.428	3.35	.002
	Busy-Mean	−1.861	.755	−.313	−2.46	.018
	Busy-SD	−.077	.863	−.013	.09	.929
	EMA-EF X Busy-Mean	−2.042	1.293	−.216	−1.58	.122
	Overall model statistics: $F(7,44) = 3.41$, $p = .005$; $R^2 = .352$					
2	Constant	62.843	10.977	–	5.73	<.001
	Age	−.072	.134	−.077	−.54	.595
	Education	.824	.309	.323	2.66	.011
	Sex	1.53	1.715	.124	.89	.376
	EMA-EF	3.350	.921	.440	3.64	<.001
	Busy-Mean	−1.801	.702	−.303	−2.57	.014
	Busy-SD	.071	.819	.012	.09	.932
	EMA-EF X Busy-SD	2.299	.824	.349	2.79	.008
	Overall model statistics: $F(7,44) = 4.52$, $p < .001$; $R^2 = .418$					

Note. $n = 52$. DAILIES = Daily Assessment of Independent Living and Executive Skills; EMA-EF = Ecological Momentary Assessment-Executive Functioning.

Supplementary analyses

Components of IADL performance

Given that Busy-Mean and Busy-SD showed differential associations with the DAILIES, we examined whether the two busyness variables were differentially associated with different aspects of daily functioning: (a) timeliness (i.e., whether a task was performed at all and during the correct timeframe) and (b) accuracy (i.e., whether a task was performed correctly). To that end, we separated the DAILIES scores into discrete *timeliness* and *accuracy* components. We then repeated the principal analyses described above, using in turn the DAILIES timeliness and the DAILIES accuracy scores as the dependent variables. The results showed that EMA-EF continued to be a significant predictor of the DAILIES beyond the two busyness variables and beyond covariates, in terms

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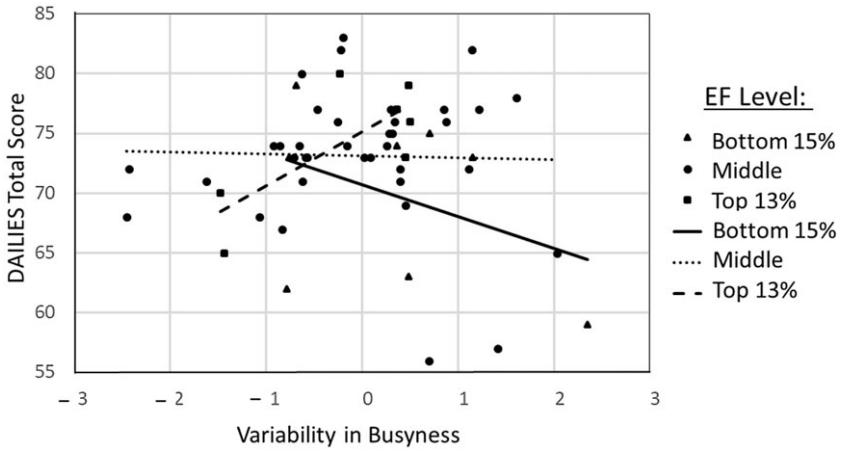

Figure 1. The figure illustrates that executive functioning moderates the association between variability in daily busyness and overall home-based IADL performance (i.e., the DAILIES Total Score), such that greater variability in busyness is associated with lower (poorer) DAILIES scores, but only for participants with lower (i.e., bottom 15% of the sample) level of executive functioning assessed via ecological momentary assessment across 18 days at home. Among those with high levels of EF, greater variability was associated with higher (better) DAILIES scores, although the variability in busyness was quite narrow, making this result difficult to interpret. DAILIES = Daily Assessment of Independent Living and Executive Skills. $n = 52$.

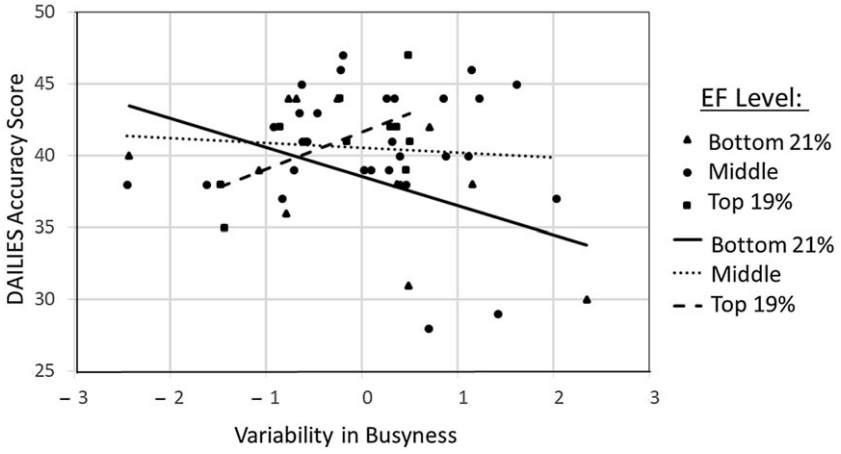

Figure 2. The figure illustrates that executive functioning moderates the association between variability in daily busyness and accuracy in home-based IADL performance (i.e., the DAILIES Accuracy Score), such that greater variability in busyness is associated with lower (poorer) DAILIES Accuracy scores, but only for participants with lower (i.e., bottom 23% of the sample) levels of executive functioning assessed via ecological momentary assessment across 18 days at home. Among those with high levels of EF, greater variability was associated with higher (better) DAILIES scores, although the variability in busyness was quite narrow, making this result difficult to interpret. DAILIES = Daily Assessment of Independent Living and Executive Skills. $n = 52$.

of both accuracy ($p = .006$) and timeliness ($p = .002$). Additionally, while Busy-Mean continued to be a significant predictor of the DAILIES beyond covariates, EMA-EF, and Busy-SD, this was true *only* for timeliness ($p = .011$), *not* for accuracy ($p = .058$). In contrast, while EMA-EF continued to significantly moderate Busy-SD, this was true *only* for accuracy ($p = .001$), *not* for timeliness ($p = .394$). Notably, this moderation effect accounted for about 16% of unique variance in the model predicting DAILIES accuracy, and Busy-Mean similarly added about 12% of variance in the model predicting DAILIES timeliness. Johnson-Neyman regions of significance revealed that Busy-SD was associated with DAILIES accuracy for participants whose EMA-EF scores fell .65 SD below the mean, corresponding to the bottom 21.15% of the sample. Specifically, for those participants with lower EMA-EF scores, DAILIES accuracy *decreased* significantly as Busy-SD increased. As before, a second region of significance emerged for participants whose EMA-EF scores fell 0.82 SD above the mean, corresponding to the top 19.23% of the sample. Paralleling the findings for overall DAILIES performance, high variability in busyness was associated with *higher* IADL accuracy for those with higher EMA-EF, but, as was the case in the principal analyses, the range of variability in busyness was narrow in this high-functioning subgroup and the results were driven by two individuals with low DAILIES scores. These moderation effects are depicted in Figure 2.

Taken together, these results suggest that (a) high variability in busyness interferes with the ability to complete tasks correctly, but only for participants with lower levels of EF, whereas (b) high levels of busyness interfere with the ability to complete daily tasks in a timely manner for all participants (regardless of their levels of EF).

Discussion

The present study examined (1) whether average *levels* of and *variability* in daily busyness would be associated with performance of IADLs at home over the span of 18 days; and (2) whether average levels of EF (across 18 days) would moderate the association between busyness and IADL performance. These questions were examined in a sample of community-dwelling older adults. The key findings are that (1) in a subset of participants who were characterized by poorer average daily EF performance, high day-to-day *variability* in busyness was associated with fewer tasks being completed *correctly*, and (2) across all participants, high *levels* of daily busyness were associated with fewer tasks being completed and/or fewer tasks being completed *on time*. Results from this study replicated and extended our prior findings in which EF moderated the deleterious impact of life complexity on at-home medication management (Suchy et al., 2020). Both studies were conducted with similar samples (i.e., well-educated, majority non-Hispanic White older adults), and in both a similar proportion of participants were deleteriously impacted by high busyness (22% in the past study versus 21% in the present sample). Additionally, the interaction between life complexity (operationalized here as variability in busyness) and EF accounted for a similar amount of variance in functioning (15% in the prior study *vs.* 16%

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in the present sample). This level of consistency between the present and the prior study mitigates concerns that present findings could be due to chance, given our relatively modest sample size. However, despite these similarities, some differences between past and present findings warrant consideration.

Most notably, while in the prior study EF interacted with self-reported *level* of life complexity in predicting a functional outcome, in the present study EF interacted with the *variability* in, *not* the *level* of, busyness. This discrepancy in findings may be explained by conceptual differences between the complexity and the busyness variables. Specifically, in the present study, participants were asked about how *busy* they were on each day relative to a typical day. In contrast, in the prior study, higher complexity scores were obtained *not* necessarily by spending more time in activities (or being "busy"), but rather by engaging in a greater number of *different activities*. It is conceivable that engaging in different activities on different days would also be associated with greater *variability* in self-reported busyness. That levels of life complexity and daily variability in busyness might be mutually analogous is also supported by the fact that both these variables (but *not* the level of busyness) correlated negatively with age, consistent with preferences for routines by those with incipient decline in functioning (Bergua et al., 2013), which itself becomes more prevalent with increasing age (Bezdicek at al., 2016). Relatedly, past research suggests that deviations from routine are particularly detrimental among older adults (Tassoni et al., 2022), and that older adults with weaknesses in EF benefit from establishment of a routine (Insel et al., 2016).

The two studies also differed in that the present study examined both the *accuracy* of task completion and the *timeliness* of task completion (i.e., whether a task was completed at all and within a prescribed timeframe), whereas the prior study only examined whether medications were taken correctly. In the present study, *accuracy* was negatively impacted by high *variability* in daily busyness, but only among those with poorer EF performance. This specific impact on accuracy is consistent with our prior findings showing that certain contextual factors that tax EF resources impact accuracy (but not speed of performance; Suchy et al., 2020), and that they deleteriously impact daily functioning (Niermeyer & Suchy, 2020b; Suchy et al., 2019), particularly if they fluctuate from day to day (Brothers & Suchy, 2022). Given that lack of routine and switching among multiple tasks likely also taxes EF resources (Beuckels et al., 2019; Rubin et al., 2022; Schneider & Anderson, 2010), it follows that it, too, would lead to IADL errors. In contrast, higher average *level* of daily busyness negatively impacted IADL *timeliness*, irrespective of participants' level of EF. This finding is intuitive, in that individuals who are busy may simply not find time for task completion. However, prior research suggests that high levels of busyness interfere with task completion only for older, not for younger, adults (Neupert et al., 2011), suggesting that an interaction between busyness and EF might emerge in a sample with a broader age range (and therefore broader EF range).

Importantly, our sample was comprised of high-functioning older adults, suggesting that even *mild* EF weaknesses are associated with resource depletion when dealing with non-routine situations, and this depletion may result in errors when executing IADLs. Indeed, in the present study (see Table 1), participants on average only earned 70% of the possible accuracy points, and all participants made at least some mistakes. Similarly, in our prior study on medication management (Suchy et al., 2020), several participants unwittingly took fewer than 70% of their medications correctly, and a significant minority took fewer than 90% correctly. In other words, functional errors (Burton et al., 2006) and gradual declines in IADLs (Bezdicek et al., 2021) are common among independently functioning older adults. These findings demonstrate the importance of assessing EF and daily functioning *in the context* of demands of daily life, especially since non-demented, independent-living older adults are highly unlikely to make many, if any, errors on IADL tasks performed in structured laboratory settings (Owsley et al., 2002; Suchy et al., 2011). In other words, the potential for lapses in IADLs in real life are likely to be missed in office-based assessments.

Taken together, the present findings provide additional support for one aspect of the ConVExA model, specifically for the notion that EF interacts with certain contextual factors in predicting IADL performance. In the present sample, this aspect of the model evidences a clear incremental utility beyond traditional EF measures, accounting for an additional 16% of variance in IADL accuracy. As such, the model shows promise as a clinically applicable tool. Of course, more work is needed before the ConVExA model can be translated into clinical practice, as the relationships between contextual factors, EF, and daily functioning need to be characterized more precisely, and instruments for quantification of contextual factors need to be developed, standardized, and normed. Nevertheless, the potential for clinical utility is clear. For example, in addition to the typical practice of interpreting *impaired* EF scores as being suggestive of impairments in daily IADLs, clinicians would also be able to interpret *intermediate* scores as being suggestive of a risk for IADL lapses *under certain circumstances*. By considering contextual assessment, clinicians could address the likelihood of specific detrimental circumstances impacting a patient's life, which would allow for more individualized recommendations. Additionally, utilizing EMA methodology might further improve ecological validity (i.e., generalizability), in line with the present study design, as such remote assessments have been found to be increasingly valid (Appleman et al., 2021; Hewitt & Loring, 2020; Marra et al., 2020) and well accepted by both patients (Chaytor et al., 2021) and the profession (Bilder et al., 2020; Postal et al., 2021).

Limitations

The primary limitation in this study is the modest sample size, which limited power and may have resulted in Type I error in some analyses. For example, it is possible that the mean level of busyness may have also interacted with EF, but that this effect was not detected. Relatedly, our moderation analyses revealed that individuals in the high EF group who also had high variability in busyness may have actually performed better on IADLs than those with lower variability. This finding is consistent with prior research showing that younger adults (whose EF is presumably higher than that of older adults) tend to manage their IADLs more effectively when they are busier (Neupert et al., 2011), and that greater busyness is associated with better cognition (Festini et al., 2016). However, in this study, this moderation was driven by only two high EF participants, and as such is difficult to interpret. Clearly then, a replication with a larger sample is needed.

Additionally, our sample was highly educated, with 81% holding a bachelor's degree or higher, whereas only about 38% of the US population achieves a similar education level (United States Census Bureau, 2022). Thus, the results may be interpreted differently in a less educated sample. For example, while in this study we interpreted lower EF as a *vulnerability* to the impact of

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variability in busyness, in a less educated sample we might instead consider that higher EF may function as a *protective* factor against the impacts of a non-routine lifestyle. Additionally, our sample was 98% non-Hispanic White (2% Hispanic White). Given the overwhelming homogeneity of our sample, it is unclear how generalizable our results are to other more diverse and less educated populations.

Another potential limitation is the way in which daily busyness was assessed. First, our busyness variable was based on self-report, which is vulnerable to biased responding. However, because data collection occurred daily, faulty memory, an example of such bias, likely did not impact the present results. Second, participants were asked to rate their daily busyness in relation to their typical level of busyness, making comparison of absolute busyness levels between participants difficult. In other words, two participants could have rated their daily busyness as a 50 out of 100 ("about as busy as usual") but have very different objective levels of busyness. However, past research has demonstrated that individuals are impacted by *deviations* from their typical routine, not just the routines themselves (Tassoni et al., 2022), which supports our assessment approach. Thus, while overall differences in objective busyness levels may have had an impact that was not quantified in the present study, our findings support that *within-person variability* in busyness had an independent impact on daily functioning. And third, participants were asked to rate their busyness at the end of the day, after they would have completed, or failed to complete, their DAILIES tasks. Thus, it is possible that on days when participants failed to complete the DAILIES tasks, they may have exaggerated their self-reported busyness as an excuse for task non-completion.

Additionally, we cannot know with absolute certainty that high levels of busyness would have the same impact on actual daily IADLs. It is possible that when individuals were unusually busy, they may have appropriately prioritized vital tasks (e.g., paying bills) while skipping less vital tasks (i.e., the study protocol). Similarly, it is possible that on busy days participants put less effort into completing the study tasks carefully, therefore making mistakes, while still completing their actual IADLs correctly. Nevertheless, the generalizability of our present results to actual daily functioning is strengthened by the fact that we previously showed that busyness interfered with participants' adherence to their *actual* medication regimen (Suchy et al., 2020).

Lastly, in contrast to typical EMA protocols (Cain et al., 2009; Campbell et al., 2020; Schmitter-Edgecombe et al., 2020), our EMA protocol involved only one measurement per day. Our design was meant to reduce participant burden given the number of other daily tasks that participants were required to complete in the original study (Brothers & Suchy, 2022). Additionally, one goal of our EMA protocol was to assess the cumulative impact of various contextual factors throughout the participants' entire day, which is why the EMA questionnaires were completed in the evening. Nonetheless, this once daily sampling may have limited our ability to fully capture daily fluctuations in EF.

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Conflicts of interest. None.

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