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Daily Assessment of Executive Functioning and Expressive Suppression Predict Daily Functioning among Community-Dwelling Older Adults

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Abstract

Objective: Executive functioning (EF) is known to be associated with performance of instrumental activities of daily living (IADLs). However, prior research has found that the degree to which EF *fluctuates* was more predictive of self-reported cognitive and IADL lapses than was *average* EF performance. One source of such EF fluctuations is engagement in an emotion regulation strategy known as expressive suppression (ES). Importantly, ES has also been shown to relate to IADL performance, presumably due to its impact on EF. However, past research is limited due to assessing IADLs only in the laboratory or via self-report. The present study examined (a) the association of daily EF and ES fluctuations with performance of *actual* IADL tasks in participants' homes, and (b) whether any significant association between ES fluctuations and daily IADLs would be mediated by daily EF variability. **Method:** Participants were 52 older adults aged 60 to 95. Over the course of 18 days while at home, participants completed daily IADL tasks as well as daily measures of EF and ES via ecological momentary assessment. **Results:** Contrary to our hypothesis, average EF across days predicted at-home IADLs above and beyond daily EF variability, which itself was also predictive. ES variability also predicted daily IADLs, and this association was fully mediated by average daily EF. **Conclusions:** Daily fluctuations in ES appear to have a deleterious impact on performance of IADLs at home, likely due to the impact of such fluctuations on EF, although the average level of EF capacity is also important.

Keywords: Instrumental activities of daily living, Daily variability, Intra-individual variability, Cognitive control, Emotion regulation, Affective suppression, Aging

Instrumental activities of daily living (IADLs) refer to functional competencies that support independent functioning, including communicating via phone or email, managing finances, or completing household chores. Much research suggests that executive functioning (EF) (i.e., a set of higher-order cognitive processes that subserve planning, selection, and execution of goal-directed behaviors; Lezak et al., 2012; Stuss & Knight, 2002; Suchy, 2015) is necessary for successful execution of IADLs (e.g., Bell-McGinty, Podell, Franzen, Baird, & Williams, 2002; Boyle et al., 2003; Jefferson, Paul, Ozonoff, & Cohen, 2006), due to its role in (a) reducing commission errors (Giovannetti, Mis, Hackett, Simone, & Ungrady, 2021), and (b) faciliating successful "meta-tasking" (i.e, interleaving of tasks; Suchy, 2015). Consequently, EF represents an important aspect of neuropsychological evalution.

However, EF is not a completely stable trait. For example, Gamaldo and Allaire (2016) found that approximately 50% of older adults' cognitive performance was not explained by between-person variability, but rather within-person variability. Although increases in intra-individual variability (i.e., greater cognitive fluctuations) can be indicative of cognitive declines (Gamaldo & Allaire, 2016), even healthy older adults experience greater EF fluctuations than younger adults (Strauss, MacDonald, Hunter, Moll, & Hultsch, 2019). Such fluctuations can be exacerbated by a variety of contextual factors, such as experience of pain, quality of sleep, and engagement in burdensome emotion regulation (e.g., Franchow & Suchy, 2017; Higgins, Martin, Baker, Vasterling, & Risbrough, 2017; Holanda, de Almondes, & Almondes, 2016; Niermeyer & Suchy, 2020a).

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Contextual Factors, Fluctuations in EF, and IADLs

Since EF is known to predict IADLs, it follows that factors that lead to EF fluctuations might also lead to fluctuations in IADLs. Indeed, considerable research supports this notion. For example, among older adults, chronic, acute, or fluctuating pain has been associated with poorer IADL performance (e.g., Eggermont et al., 2014; Williams et al., 2006) and future IADL declines (Thakral et al., 2019). Similarly, sleep disorders (Hanewinckel et al., 2015; Spira, Chin-Edinborough, Wu, & Yaffe, 2014) and poor sleep quality have been related to poor IADL performance (e.g., Fung et al., 2012; Holfeld & Ruthig, 2012) and future IADL impairment (e.g., Park, Buchman, Lim, Leurgans, & Bennett, 2014; Spira et al., 2012).

In contrast to the relatively extensive research on the association of pain and sleep with daily functioning, only two studies to our knowledge examined the impact of burdensome emotion regulation on functionality, and both of these specifically focused on an emotion regulation strategy known as expressive suppression (ES; Niermeyer & Suchy, 2020b; Suchy, Niermeyer, Franchow, & Ziemnik, 2019). ES is used commonly and involves deliberate inhibition of emotional expressions (e.g., laughter, frowning) to facilitate socially appropriate conduct (Gross, 1998). In contrast to other emotion regulation strategies like cognitive reappraisal, ES is thought to be particularly burdensome, partly because it typically occurs *after* an emotional response has been activated (Cutuli, 2014). Additionally, while cognitive reappraisal dampens both the subjective experience of emotion and the concomitant physiologic arousal, ES accomplishes neither and may, at times, even heighten both (e.g., John & Gross, 2004; Li et al., 2017). Importantly, excessive recent engagement in ES can temporarily impact subsequent EF performance (e.g., Baumeister, 2002; Baumeister, Schmeichel, & Vohs, 2007; Szczygieł & Maruszewski, 2015), but does not seem to impact other cognitive domains, as evidenced by experimental (e.g., Franchow & Suchy, 2017; Schmeichel, 2007) and correlational research (Franchow & Suchy, 2015; Niermeyer, Ziemnik, Franchow, Barron, & Suchy, 2019; Niermeyer & Suchy, 2020a, 2020b; Suchy, Brothers, Mullen, & Niermeyer, 2020). Additionally, similar to the impact of sleep and pain on IADLs, self-reported recent burden of ES is associated with subsequent slower dual-task walking (Niermeyer & Suchy, 2020b) and less accurate performance on subsequently-administered office-based IADL tasks (Suchy et al., 2019). Notably, in both studies, the association between ES and functionality was fully mediated by EF.

In summary, past research suggests (a) EF plays a role in performance of IADLs, (b) engagement in ES leads to subsequent temporary declines in EF, which over time present as EF *fluctuations*, and (c) engagement in ES impacts future IADL performance, presumably due to its impact on EF. Taken together, these findings imply that daily *fluctuations* in EF should lead to more frequent lapses in IADLs. Such an association was found in a recent study by Schmitter-Edgecombe, Sumida, and Cook (2020). This study utilized ecological momentary assessment (EMA)[1] to assess EF four times daily for 7 days and used the EMA performance as a predictor of (a) an office-based *objective* measure of functional status and (b) *self-reported* cognitive/functional lapses in daily life. Because EMA assessments are completed at home and are embedded within the context of other daily activities, the study captured not only the *level* of EF (i.e., the average across assessments), but also the daily EF *fluctuations* (i.e., the SD across assessments). The results showed that older adults with more *fluctuations* in EF *self-reported* experiencing higher levels of functional lapses in daily life. In contrast, those with higher *average* EF scores tended to score better on an *objective* lab-based measure of functional status; there was no association between average EMA scores of EF and self-reported functional lapses. These findings suggest that variability in EF, as compared to average EF performance, may play a more significant role in executing IADLs in daily life.

Limitations of Past Research

Prior studies have one salient limitation in that they relied on two methods of IADL assessment that likely do not adequately capture at-home functioning. Specifically, Schmitter-Edgecombe et al. (2020) and Suchy et al. (2019) assessed IADLs in controlled laboratory conditions, allowing for optimal performance under ideal circumstances. Such an approach fails to capture the complexity of daily life that typically requires the interleaving of daily tasks and demands. To address this limitation, Schmitter-Edgecombe et al. (2020) supplemented their office-based assessment with self-reports, which reflect individuals' perception of their functioning at home. While this method may better capture the impact of interruptions and interfering state factors (e.g., Schmitter-Edgecombe et al., 2020), self-reported IADLs have been shown to be inaccurate for at least a substantial subset of older adults (e.g., Suchy, Kraybill, & Franchow, 2011).

The Present Study

The purpose of the present study was to address the main limitations of past research by replacing self-report and office-based IADL assessments with *real-world* daily IADL tasks completed at home over the course of three weeks. Using this highly ecological IADL measure, we aimed to (1) test the Schmitter-Edgecombe et al. (2020) assertion that daily EF variability is a better predictor of daily functioning than average EF performance, and (2) validate, in the home environment, our prior laboratory-based findings that variability in ES is an indirect contributor to IADL lapses, and that this effect is mediated by EF (Suchy et al, 2019).

[1]EMA is a methodology that samples behavior, performance, and/or self-report of subjective experiences daily (or even multiple times a day), either on a predetermined or variable schedule.

To accomplish these aims, we recruited older adults who agreed to complete IADL-like tasks (e.g., rescheduling an appointment, grocery shopping, filling out a reimbursement form) in the context of their daily lives across three weeks. Participants concurrently completed daily EMA to assess their average daily ES and EF and their daily variability in ES and EF. The reason for following our participants for three weeks was to capture daily fluctuations and associated real-world functional lapses. Based on past research, we hypothesized (1) greater variability in daily EF would relate to poorer performance on at-home IADL tasks, above and beyond average level of daily EF; (2) greater variability in ES would be associated with poorer performance on at-home IADL tasks; and (3) any significant association between ES variability and performance on at-home IADL tasks would be fully mediated by daily EF variability.

METHOD

Participants

Participants were 54 independently living older adults recruited as part of a larger study through the University of Utah's Center on Aging database, the Osher Lifelong Learning Institute, and a Senior Expo. Inclusion criteria included being 60 years or older, having at least an 8th grade education, and being able to read/understand English.

Potential participants were excluded if they had (a)uncorrected hearing, vision, or motor impairments that would affect task performance; (b) a self-reported diagnosis of dementia, mild cognitive impairment, moderate to severe traumatic brain injury, stroke, seizure disorder, or other significant psychiatric or neurological disorder, as we are interested in how ES impacts EF and IADLs in *neurologically and cognitively healthy* older adults; or (c) missing data (a failure to complete baseline assessment; $n = 1$; a failure to complete daily tasks; $n = 1$). The final sample consisted of 52 older adults aged 60 to 95 ($M = 69.5$, $SD = 6.35$), primarily Caucasian (98%) and female (65.4%). See Table 1 for additional sample characteristics.

Procedure

The study was approved by the University of Utah Institutional Review Board and complied with institutional research standards for human research in accordance with the Helsinki Declaration. Participants underwent a phone screening to determine eligibility. Those who qualified were invited for a baseline assessment at the University of Utah. Participants were consented before completing measures of EF and ES, and additional cognitive/psychological/psychophysiological testing as part of a larger study. At the end of the session, participants were given detailed instructions and sent home with daily tasks to complete six days a week over the next three weeks. Participants received $60 for the 6-hour baseline testing session, $4 for every daily task and $4 for every daily survey, for up to an additional $144. Interested participants received brief feedback on their personality, cognition, and psychiatric symptoms as assessed by screening measures, and community resources.

Table 1. Demographic, cognitive, and affective characteristics of the sample

	N	Range	Mean(*SD*)
Age	52	60-95	69.5(*6.35*)
Education	52	12-22	16.87(*2.34*)
DRS Scaled	52	7-16	11.60(2.14)
TOPF Standard	51	91-129	112.41(*9.35*)
GDS Raw	48	0-14	3.73(*3.52*)
Baseline EF_{speed}	52	8.38-16.50	12.37(*1.56*)
Baseline EF_{errs}	52	7.13-12.63	11.14(*.971*)
EMA EF_{Avg}*	52	−4.16-1.23	.00(*.833*)
EMA EF_{SD}*	52	−1.24-2.72	.00(*.826*)
Baseline *ES*	52	0-37	8.83(*9.08*)
EMA ES_{Avg}	52	4-56	38.08(*12.30*)
EMA ES_{SD}	52	1-28	14.87(6.71)
DAILIES	52	55-81	70.60(*6.21*)

Note. * = z-score, where *mean* = 0; DRS = Dementia Rating Scale – 2nd Edition; TOPF = Test of Premorbid Functioning; GDS = Geriatric Depression Scale; SD = Standard Deviation; Baseline EF_{speed} = composite of speeded scores on four timed subtests of the Delis-Kaplan Executive Function System (D-KEFS) battery at baseline; Baseline EF_{errs} = composite of error scores on four timed subtests of the Delis-Kaplan Executive Function System (D-KEFS) battery. EMA EF_{Avg} = average executive functioning performance across 18 days of assessment at home; EMA EF_{SD} = standard deviation of executive functioning performance across 18 days of assessment at home; Baseline *ES* = self-reported expressive suppression on the Burden of State Emotion Regulation Questionnaire (B-SERQ) at baseline in lab; EMA ES_{Avg} = average self-reported expressive suppression burden across 18 days of assessment at home; EMA ES_{SD} = standard deviation of self-reported expressive suppression burden across 18 days of assessment at home; *DAILIES* = score based on performance of daily IADL tasks over 18 days.

Measures

Characterizing the Sample

General cognitive status and premorbid intelligence were assessed using the Dementia Rating Scale – Second Edition (DRS-2; Jurica, Leitten, & Mattis, 2001) and the Test of Premorbid Functioning (TOPF; Pearson Assessment, 2009). Depression was assessed using the 30-item self-report Geriatric Depression Scale (GDS; Yesavage, 1988). See Table 1.

Daily Functioning

Daily IADLs were assessed using the Daily Assessment of Independent Living and Executive Skills (DAILIES) protocol, developed in our laboratory. The DAILIES consists of 18 tasks (e.g., rescheduling an appointment, filling out a reimbursement form; see supplementary material Appendix 1) for participants to complete over the course of three weeks. This is the first study to include the DAILIES protocol.

Participants were instructed to complete one task daily and provide their answer using a specific method of communication (e.g., participants were instructed to either leave a voicemail on the lab phone, email the lab account, or respond via postal mail). A variety of methods were chosen to increase ecological validity, though the method was standardized for each task. Participants were instructed to submit their responses during a *specified time of day,* thereby having to incorporate the completion of the DAILIES tasks within the rest of their daily routine. During baseline assessment in the laboratory, participants completed two practice tasks to ensure they understood the procedure. Most tasks took approximately 5 minutes to complete.

Daily tasks were scored based on timeliness and accuracy. Participants received one point each for completing the task on the correct day and the correct time of day (as evident per time stamps of phone messages, emails, postal stamp, etc.). Additional points were awarded based on performance accuracy, ranging from 1 to 7 points depending on task complexity. The sum of total scores earned on each task, comprising both timeliness and accuracy, was used in analyses and is referred to as "DAILIES" hereafter.

Ecological Momentary Assessment (EMA)

To assess daily fluctuations in ES and EF, participants completed a daily EMA survey on their smart phone or tablet. EMA has been shown to be appropriate and reliable with older adults (e.g., Schweitzer et al., 2017). Participants received a link to a Qualtrics survey Monday through Saturday at 7:00 PM (to be completed before bed), inquiring about the effort expended on ES over the past 24 hours. Participants were asked two questions about how much they needed to suppress during the day and how much effort they exerted to do so (Appendix 2). From the daily ES data, we calculated two overarching variables: (a) each participant's average daily ES burden across the three weeks (Cronbach's alpha = .863), and (b) variability in daily ES (i.e., standard deviation) across the three weeks. Hereafter, these variables are referred to as EMA "ES_{Avg}" and "ES_{SD}," respectively.

After survey completion, participants completed two EF tasks, utilizing Stroop (Stroop, 1935) and digit span paradigms (Wechsler, 2008). The Stroop task was comprised of names of common furniture (baseline condition) or colors (inhibition condition) written in red, blue, or yellow ink. Below each word, participants selected (from three available colors) the color of ink the word was written in. The baseline condition was administered first and lasted 20 seconds, followed by a 20-second inhibition condition. The difference between baseline and inhibition trials was computed to isolate inhibition, both for the total number of correct responses and the number of errors daily. We then computed the means and SDs of these variables across the 18 days. To combine the numbers of responses and errors into one variable, we converted these means and SDs to z-scores to place them on the same metric, generating Stroop mean and Stroop SD scores. The digit span task was comprised of 12 strings of numbers increasing in length by one digit every 2 trials (ranging from 3 to 8). Participants had a standard amount of time to view each string (adjusted for number of digits) and then typed the digits in reverse order. The number of items answered correctly each day was recorded and an 18-day mean and SD were computed. To quantify participants' *overall* EF performance, Stroop and digit span means and SDs were converted to z-scores (based on the sample) to place them on the same metric and then combined into a single EMA "EF_{Avg}" and "EF_{SD}" for use in analyses. Correlation coefficients between EF composite scores and corresponding Stroop and digit span scores all exceeded .84, suggesting good internal consistency.

Validation of EMA Assessment

To validate the EMA EF tasks, we used a widely accepted battery of EF tests, the Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan, & Kramer, 2001). Consistent with past research (e.g., Franchow & Suchy, 2017; Suchy et al., 2020), we used the Letter-Number Switching, three Design Fluency conditions, three Verbal Fluency conditions, and the Color-Word Interference and Interference-Switching conditions to generate two EF composite scores (i.e., means across subtests), one based on speed and one based on accuracy. Raw scores from relevant conditions in all subtests were converted to scaled scores based on the norms for adults aged 60-69; using this single age-band for normative comparison allowed us to generate clinically interpretable composite scores while *not* correcting for age. These composites are referred to as Baseline "EF_{speed}" and "EF_{errs}."

To validate the EMA assessment of ES, we used the Burden of State Emotion Regulation Questionnaire (B-SERQ) at baseline. The B-SERQ is a 14-item self-report questionnaire that assesses the burden of naturally-occurring ES over the 24 hours *prior* to testing. It has been validated by prior research, with Cronbach's alphas ranging from .81 to .91 (Franchow & Suchy, 2015; Niermeyer et al., 2019; Niermeyer & Suchy, 2020a; Suchy et al., 2019, 2020). Due to administration error, three participants received a version of the B-SERQ that asks about ES burden "today" instead of "in the past 24 hours." The sample means for "24 hours" and "today" were similar ($M = 9.67$ and 8.78, respectively) and results of the analyses were unchanged when the three "today" participants were removed. Thus, all participants were used in analyses. We refer to the total B-SERQ scores as "Baseline ES."

RESULTS

Preliminary Analyses

Data Distribution

The data were examined for normality using Q-Q plots, skewness, and kurtosis. Three variables were slightly skewed (skewness > 1.0 and < 2.5), with 1-2 outliers identified for each variable. Because these outliers reflected performance in the low average range, they were not excluded from

Table 2. Correlations among lab-based and home-based EF and ES variables and demographic variables, using bootstrapping

	Age	Education	GDS
Baseline EF_{speed}	−.512 (−.647, −.304)*	.086 (−.188, .370)	−.078 (−.365, .277)
Baseline EF_{errs}	−.305 (−.511, −.046)*	.050 (−.027, .558)	−.111 (−.376, .084)
Baseline *ES*	.083 (−.151, .308)	−.275 (−.531, −.002)*	.157 (−.090, .471)
EMA EF_{Avg}	−.203 (−.396, .015)	.208 (−.176, .532)	.030 (−.129, .193)
EMA EF_{SD}	.140 (−.164, .387)	−.240 (−.501, .020)	−.004 (−.253, .239)
EMA ES_{Avg}	−.056 (−.330, .191)	.133 (−.155, .370)	.164 (−.110, .394)
EMA ES_{SD}	−.003 (−.217, .248)	−.199 (−.459, .114)	.101 (−.101, .300)
DAILIES	−.129 (−.456, .138)	.215 (−.091, .487)	.185 (−.001, .372)

Note. * = 95% confidence intervals generated with bootstrapping (n = 1000) that do not cross 0, indicating significance; GDS = Geriatric Depression Scale total raw score; Baseline EF_{speed} = composite of speeded scores on four timed subtests of the Delis-Kaplan Executive Function System (D-KEFS) battery at baseline; Baseline EF_{errs} = composite of error scores on four timed subtests of the Delis-Kaplan Executive Function System (D-KEFS) battery; Baseline *ES* = self-reported expressive suppression on the Burden of State Emotion Regulation Questionnaire (B-SERQ) at baseline in lab; EMA EF_{Avg} = average executive functioning performance across 18 days of assessment at home; EMA EF_{SD} = standard deviation of executive functioning performance across 18 days of assessment at home; EMA ES_{Avg} = average self-reported expressive suppression burden across 18 days of assessment at home; EMA ES_{SD} = standard deviation of self-reported expressive suppression burden across 18 days of assessment at home; *DAILIES* = score based on performance of daily IADL tasks over 18 days.

Table 3. Correlations among lab-based and home-based EF and ES variables, using bootstrapping

	Baseline *ES*	EMA EF_{Avg}	EMA EF_{SD}	EMA ES_{Avg}	EMA ES_{SD}
Baseline EF_{speed}[a]	−.244 (−.557, .108)	.484 (.195, .715)*	.−.044 (−.469, .373)	.063 (−.179, .288)	−.100 (−.358, .153)
Baseline EF_{errs}[b]	−.438 (−.742, −.065)*	.672 (.354, .880)*	−.533 (−.767, −.253)*	−.011 (−.238, .307)	−.166 (−.408, .109)
Baseline *ES*		−.422 (−.764, −.073)*	.227 (−.072, .648)	−.042 (−.267, .198)	.358 (.110, .547)*
EMA EF_{Avg}			−.567 (−.795, −.281)*	−.036 (−.163, .272)	−.330 (−.509, −.057)*
EMA EF_{SD}				−.093 (−.319, .132)	.314 (.055, .551)*
EMA ES_{Avg}					−.449 (−.661, −.096)*

Note. * = confidence intervals generated with bootstrapping (n = 1000) that do not cross 0, indicating significance
a = for the speed composite, higher scores reflect better performance
b = for the Error composite, lower scores mean more errors
Baseline EF_{speed} = composite of speeded scores on four timed subtests of the Delis-Kaplan Executive Function System (D-KEFS) battery at baseline
Baseline EF_{errs} = composite of error scores on four timed subtests of the Delis-Kaplan Executive Function System (D-KEFS) battery at baseline
Baseline *ES* = self-reported expressive suppression on the Burden of State Emotion Regulation Questionnaire (B-SERQ) at baseline in lab
EMA EF_{Avg} = average executive functioning performance across 18 days of assessment at home
EMA EF_{SD} = standard deviation of executive functioning performance across 18 days of assessment at home
EMA ES_{Avg} = average self-reported expressive suppression burden across 18 days of assessment at home
EMA ES_{SD} = standard deviation of self-reported expressive suppression burden across 18 days of assessment at home

analyses. Instead, we used the "boot" package in R to use bootstrapping, which minimizes the impact of such outliers while still including them. Additionally, all cognitive measures evidenced a steady practice effect across all 18 days. The practice effect was not factored into any analyses.

Descriptive Statistics and Zero-Order Correlations

See Table 1 for descriptive statistics on the demographics, as well as dependent and independent variables. Zero-order correlations between demographics and dependent and independent variables are presented in Table 2.

Validation of EMA Variables

As a prerequisite to principal analyses, we examined whether the EMA variables (i.e., daily measurements of ES and EF) represented the intended constructs by examining correlations between the EMA variables assessed at home and the relevant baseline variables assessed in the lab. As seen in Table 3, EMA EF_{Avg} was associated with both baseline EF_{speed} and baseline EF_{errs}, which suggests that the *level* of EF performance at home does in fact tap into the EF construct as assessed via previously validated measures. In other words, individuals who performed better on measures of EF in the lab were likely to perform better, on average, at home. Additionally, EMA EF_{SD} was associated with baseline EF_{errs}, suggesting that individuals who make more errors under ideal conditions (i.e., within the structure of office-based assessment) are more likely to demonstrate increased variability in their EF performance when confronted with the complexities of daily life.

As also seen in Table 3, EMA ES_{SD} correlated with baseline *ES*, suggesting that individuals who reported engaging in less ES in the 24 hours prior to baseline visit had less variability in ES at home. Conversely, EMA ES_{Avg} was *not* significantly associated with baseline *ES*, consistent with the notion

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Table 4. Hierarchical linear regressions of daily EF and ES predicting daily IADL performance (DAILIES)

Model	Step	Predictor	R^2	R^2 Δ	FΔ	df	*p*-value
1	1	EMA EF_{Avg}	.272	–	18.642	1, 50	<.001**
	2	EMA EF_{SD}	.280	.009	.597	1, 49	.443
2	1	EMA EF_{SD}	.139	–	8.056	1, 50	.007**
	2	EMA EF_{Avg}	.280	.142	9.641	1, 49	.003**
3	1	EMA ES_{Avg}	.001	–	.033	1, 50	.857
	2	EMA ES_{SD}	.108	.107	5.899	1, 49	.019*

*Note.*** = significance at the $p < .01$ level
* = significance at the $p < .05$ level
EMA EF_{Avg} = average executive functioning performance across 18 days of assessment at home
EMA EF_{SD} = standard deviation of executive functioning performance across 18 days of assessment at home
EMA ES_{Avg} = average self-reported expressive suppression burden across 18 days of assessment at home
EMA ES_{SD} = standard deviation of self-reported expressive suppression burden across 18 days of assessment at home

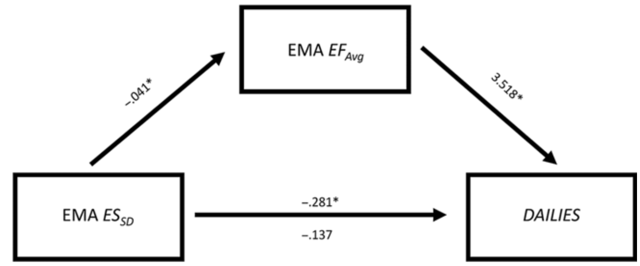

Fig. 1. Mediation model analysis. EMA ES_{SD} and EMA EF_{Avg} were both significantly related to each other and to *DAILIES* ($p < .05$). However, once EMA EF_{Avg} was added into the model, EMA ES_{SD} was no longer as significant predictor of *DAILIES*; further analysis revealed that EMA EF_{Avg} fully and significantly mediated the relationship.
DAILIES = score based on performance of daily IADL tasks.
EMA EF_{Avg} = average executive functioning performance across 18 days of assessment at home.
EMA ES_{SD} = standard deviation of self-reported expressive suppression burden across 18 days of assessment at home.

that reports of acute ES in the past 24 hours are not reflecting stable long-term ES levels. Beyond correlations with baseline ES, the relationships between the EMA ES and EF variables were consistent with prior research. Specifically, EMA ES_{SD} was significantly associated with EMA EF_{SD} and EF_{Avg} suggesting that variability in ES at home is related to both variability and level of EF performance at home. This mirrors prior research in which recent ES was associated with EF errors in the lab (Suchy et al., 2020), a relationship that was also replicated in the present study. Since both baseline EF_{errs} and baseline EF_{speed} were associated with age, we also ran partial correlations controlling for age and the results did not change.

Principal Analyses

To address the first hypothesis that variability in EF at home (i.e., EMA EF_{SD}) predicts daily task performance (i.e., *DAILIES*) beyond the level of EF performance at home (i.e., EMA EF_{Avg}), we ran a hierarchical linear regression with bootstrapping ($n = 1000$) in RStudio Version 1.1.462 using the "boot" package. *DAILIES* was entered as the dependent variable, with EMA EF_{Avg} and EMA EF_{SD} entered as predictors on Steps 1 and 2, respectively. As seen in Table 4 Model 1, contrary to expectation, EMA EF_{SD} did *not* predict daily IADL performance (i.e., *DAILIES*) beyond EMA EF_{Avg}. When reversing the order of variable entry (Table 4 Model 2), EMA EF_{SD} predicted *DAILIES* by itself in Step 1, with EMA EF_{Avg} predicting *DAILIES* above and beyond EMA EF_{SD}. These findings suggest that the level of daily EF performance is a stronger predictor of daily IADL functioning than is EF variability, contrary to prediction.

To address the second hypothesis that variability in ES is related to poorer performance of IADLs at home, we again ran a hierarchical linear regression with bootstrapping ($n = 1000$), with *DAILIES* as the dependent variable. Paralleling our approach to the first hypothesis, we entered EMA ES_{Avg} and EMA ES_{SD} in Steps 1 and 2, respectively (Table 4 Model 3). The results confirmed that EMA ES_{SD} was not only a significant predictor of *DAILIES*, but that it predicted *DAILIES* above and beyond EMA ES_{Avg}, which was not significant. These results suggest that variability in ES is more important in the execution of daily tasks than average level of ES.

The third hypothesis was that any significant associations between ES variability and performance on daily tasks would be mediated by EF variability. However, since EF level was a stronger predictor of *DAILIES* than was EF variability, we altered our initially planned model, examining instead whether the relationship between EMA ES_{SD} and *DAILIES* was mediated by EMA EF_{Avg}. To do so, the "mediation" package in R was used in addition to the bootstrap function ($n = 1000$). One model was created where *DAILIES* was regressed onto EMA ES_{SD}, another model had EMA EF_{Avg} regressed onto EMA ES_{SD}, and finally a model where *DAILIES* was regressed onto EMA ES_{SD} and EMA EF_{Avg}. See Figure 1. Per the results of the first model, EMA ES_{SD} significantly predicted *DAILIES*. However, once EMA EF_{Avg} was added into the model, it alone significantly predicted *DAILIES,* while EMA ES_{SD} was no longer significant. These findings, along with the significant indirect effect (CI = -.315, −.02), are consistent with EMA EF_{Avg} fully mediating the relationship between daily ES variability and daily IADL performance.

DISCUSSION

The present study examined whether variability in ES and EF would be associated with real-world daily IADL functioning among older adults. The key findings are (a) average daily level of EF was a better predictor of daily IADL performance

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than daily EF variability, contrary to prediction; (b) daily ES variability was significantly negatively associated with daily IADL performance; and (c) the association between daily ES variability and daily IADL performance was fully mediated by average daily level of EF. These findings extend prior research by demonstrating that daily variability in ES has an impact on actual daily functioning at home, both in terms of cognition and IADLs. The present study was the first to examine the associations among these variables using EMA methodology in conjunction with real-world daily IADL performance.

Our finding that average EF was more predictive of daily task performance than EF variability was inconsistent with prior research (Schmitter-Edgecombe et al., 2020). There are several possible explanations for this discrepancy. First, the Schmitter-Edgecombe study examined self-reported functional lapses instead of objective daily performance. It could be participants are more aware of *lapses* in functioning than consistently poor functioning. Consequently, individuals who experience more variability likely self-report more difficulties than do individuals who perform more consistently, regardless of their actual *level* of performance. Second, given that average EF (i.e., EMA EF_{Avg}) and EF variability (i.e., EMA EF_{SD}) are moderately negatively correlated (Table 3), one could conceptualize average EF as encompassing *both* the variability in EF *and* one's overall EF ability. Since individuals with increased variability in EF tend to have lower average EF (Table 3), and those with poorer EF ability generally have poorer IADL performance (e.g., Jefferson et al., 2006), it follows that individuals who have both greater variability in EF *and* poorer EF capacity would have the lowest mean EF performance when assessed across days. These individuals would then be at the greatest risk of poorer IADL performance.

The present study was also the first to confirm that ES variability across days relates to daily variability in EF and to daily IADL performance. The association between ES and EF, in more general terms, has been well established. For example, previous research has established that ES shares neural underpinnings with EF (most notably frontal-lobe networks; e.g., Hermann, Bieber, Keck, Vaitl, & Stark, 2014), and that those who perform better on measures of EF also suppress emotions more effectively (Gyurak, Goodkind, Kramer, Miller, & Levenson, 2012). Additionally, like EF, ES is important for successful navigation of daily social situations, such as regulating negative emotions during conflict (Thomson, Overall, Cameron, & Low, 2018). However, likely due to the overlap between the two constructs, ES also appears to transiently deplete EF and lead to transiently poorer EF performance (e.g., Baumeister et al., 2007; Franchow & Suchy, 2017). Thus, our findings that variability in ES is correlated with both mean EF and the variability in EF are consistent with prior research. Notably, we cannot establish causation from the present results. Daily fluctuations in ES engagement may have a corresponding effect on EF variability, thereby also having an impact on overall level of EF. Alternatively, individuals who have lower mean EF may be more likely to exhibit fluctuations in EF and concomitant lapses in emotion regulation. Indeed, poorer EF is often associated with less frequent and effective use of cognitive reappraisal (McRae, Jacobs, Ray, John, & Gross, 2012), necessitating greater reliance on ES. This lack of clear causality also has ramifications for the interpretation of mediation results, since definitive conclusions about mediation can be made *only if* the mediator (in this case, EF) is measured after the predictor (in this case, ES). Thus, future research should examine these associations either in an experimental design or by temporally separating the measurement of ES and EF.

The present study took a novel approach to measuring real-world IADL functioning by having participants complete IADL tasks at home as part of their daily routine. While there has been interest in at-home IADL evaluations for clinical purposes (e.g., Zilbershlag & Josman, 2019), typical IADL research primarily utilizes self-report questionnaires, or lab-based measures with discrete IADL tasks. Although such measures resemble tasks people complete in their homes, there is evidence that real-world IADL functioning is actually better predicted by measures of EF than by lab-based IADL tasks (Ziemnik & Suchy, 2019). To address these limitations, a few studies have attempted to target real-world functioning. For example, one study presented participants with a list of tasks (e.g., making lunch, changing a light bulb, demonstrating their medication routine) to complete at home during a brief observation (less than 2 hours; Weakley & Schmitter-Edgecombe, 2019). Although this approach allows participants to complete tasks they would complete regardless of being in a study, the single observation period precludes measurement of daily variation or the capacity to spontaneously interleave study tasks with other daily routines.

To facilitate assessment of participants' ability to complete IADLs in a natural and representative manner, researchers have recently begun looking towards utilizing Smart Home technology, such as sensors and videos that capture older adults' daily functioning (Jekel, Damian, Storf, Hausner, & Frolich, 2016). However, this approach is costly and invasive, making it impractical for many researchers and unattractive to many participants. Additionally, there may be variation in which IADLs a participant chooses to complete, particularly if they have a partner (e.g., one partner manages finances, the other prepares meals). To avoid inconsistency across participants, some studies have instead focused on specific IADLs, such as actual at-home medication management (e.g., Pasina et al., 2014; Suchy et al., 2019; Thiruchselvam et al., 2012). Obviously, however, such studies are limited in that they cannot necessarily comment on performance of other IADLs. The present study, by requiring participants to complete a variety of IADL tasks that encompass multiple IADL categories (e.g., shopping, communication, transportation) and to do so in the context of their daily lives, offers a unique insight into factors that impact participants' completion of various IADLs without being overly invasive or cost-prohibitive.

Limitations

First, the present sample was fairly homogenous (e.g., healthy, well-educated, Caucasian). Since factors like education are often related to EF (Dorbath, Hasselhorn, & Titz, 2013), it is unclear how the results would translate to more heterogenous samples with less education. Additionally, it would be important to examine whether present results would replicate among individuals with cognitive impairment or poor physical or mental health. Furthermore, there are cultural considerations. For example, ES is used commonly in some Asian cultures and does not seem to have the same negative effect on cognition, perhaps due to extensive practice (e.g., Chen, Burton, & Bonanno, 2020; Soto, Perez, Kim, Lee, & Minnick, 2011). Consequently, ES engagement may not impact EF or IADL performance in such populations, and replication with more diverse samples is warranted.

Second, while we took care to develop tasks that resemble typical IADLs in daily life, this is the first study to use the DAILIES protocol. Normative data for the DAILIES do not exist, nor has it been validated with other measures of daily functioning. Consequently, it is not clear what constitutes normatively "good" or "bad" performance. Additionally, although we instructed participants to complete tasks independently, participants may have received help from partners or family. Alternatively, participants may have had difficulties successfully integrating our tasks into their normal daily routines or may have not put forth the effort they would have on tasks with real-world ramifications. That said, participants received $4 per completed task, making the benefit relatively comparable to the financial benefits experienced in daily life, such as canceling appointments to avoid penalties or filling out rebate forms to receive discounts. Still, further validation and norming of the DAILIES is needed.

Third, our EMA measures of EF and ES have not been previously validated. However, we used well-validated EF paradigms, i.e., the Stroop task and digit span (Delis et al., 2004; Wechsler, 2008) and questions from a well-validated ES measure (Franchow & Suchy, 2015). Importantly, we found expected associations between the EMA EF variables and previously validated laboratory measures. Additionally, unlike typical EMA research, our EMA sampling was done only once a day, precluding detection of fluctuations during the day. Finally, while our sample size was larger than similar studies using EMA data (Schmitter-Edgecombe et al., 2020), it was still modest, which limited statistical power. However, repeated EMA assessment across 18 days served to strengthen the reliability.

Future Directions

Future research should examine temporal associations between ES, EF, and IADLs to allow better causal determinations, as well as to determine whether ES on a given day increases the risk for lapses that day, or in the subsequent days. Differences in patterns across time should also be examined to determine what types of variability are most detrimental (e.g., consistent variability throughout the study vs. variability on days or weeks vs. variability through the day). Finally, other factors known to deplete EF and cognitive functions (e.g., pain, sleep; see Weizenbaum, Torous, & Fulford, 2020, for a review), and cognitive fatigue (Blain, Hollard, & Pessiglione, 2016) should also be examined to determine what impact they may have on daily fluctuations in EF and IADLs.

SUPPLEMENTARY MATERIAL

To view supplementary material for this article, please visit https://doi.org/10.1017/S1355617721001156

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CONFLICTS OF INTEREST

None.

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