Received: 7 July 2023 | Accepted: 27 October 2023

DOI: 10.1002/dad2.12506

Alzheimer's & Dementia
Diagnosis, Assessment & Disease Monitoring

RESEARCH ARTICLE

Using a digital tool to detect early changes in everyday functioning in older adults: A pilot study of the Assessment of Smartphone Everyday Tasks (ASSET)

Mark A. Dubbelman[1,2] | Tia C. Hall[2] | Isabella M. Levesque[2] | Kayden J. Mimmack[1] | Sietske A. M. Sikkes[3,4] | Shira H. Fischer[5] | Dorene M. Rentz[1,2] | Reisa A. Sperling[1,2] | Kathryn V. Papp[1,2] | Rebecca E. Amariglio[1,2] | Gad A. Marshall[1,2]

[1]Department of Neurology, Massachusetts General Hospital, Harvard Medical School, Boston, Massachusetts, USA

[2]Department of Neurology, Center for Alzheimer Research and Treatment, Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts, USA

[3]Department of Neurology, Alzheimer Center Amsterdam, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands

[4]Faculty of Behavioral and Movement Sciences, Clinical Developmental Psychology and Clinical Neuropsychology, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands

[5]RAND Corporation, Boston, Massachusetts, USA

Correspondence
Gad A. Marshall, Center for Alzheimer Research and Treatment, Brigham and Women's Hospital, 60 Fenwood Rd, 9016P, Boston, MA 02115, USA.
Email: gamarshall@bwh.harvard.edu

Funding information
NIH/NIA, Grant/Award Number: R42 AG069629; Alzheimer Nederland, Grant/Award Number: WE.06-2023-02

Abstract

INTRODUCTION: To investigate the utility of a new digital tool for measuring everyday functioning in preclinical Alzheimer's disease, we piloted the Assessment of Smartphone Everyday Tasks (ASSET) application.

METHODS: Forty-six participants (50.3 ± 27.1 years; 67% female; 20 young unimpaired, 17 old unimpaired, 9 mildly cognitively impaired) completed ASSET 7 times. ASSET comprises two main tasks, simulating a Patient Portal and a Calendar. We assessed ASSET's internal consistency, test–retest reliability, and user experience.

RESULTS: ASSET main tasks correlated with each other ($r = 0.75$, 95% confidence interval [CI] = [0.58, 0.86]). Performance on ASSET's Patient Portal related to cognition ($r = 0.64$, 95% CI = [0.42, 0.79]) and observer ratings of everyday functioning ($r = 0.57$, 95% CI = [0.24, 0.79]). Test–retest reliability was good (intraclass correlation coefficient = 0.87, 95% CI = [0.77, 0.93]). Most participants rated their experience with ASSET neutrally or positively.

DISCUSSION: ASSET is a promising smartphone-based digital assessment of everyday functioning. Future studies may investigate its utility for early diagnosis and evaluation of treatment of Alzheimer's disease.

KEYWORDS
Alzheimer's disease, application, digital, everyday functioning, instrumental activities of daily living, smartphone

1 | INTRODUCTION

Alzheimer's disease (AD) is characterized by gradual cognitive decline eventually resulting in dementia.[1] Over the years preceding the dementia diagnosis, performance of cognitively complex "instrumental activities of daily living" (IADL), such as making appointments, using electronic devices and managing finances, deteriorates.[2] IADL reflect a person's capacity to function independently in everyday life and as such are clinically meaningful, even in early disease stages.

IADL are commonly measured using self- or observer-reported outcome measures,[3] which probe the subjective experience of the participant or patient, or that of someone close to them. Numerous studies have shown the utility of both self-reported and observer-reported everyday functioning in diagnosis and disease monitoring.[2,4–9] Some have pointed out that these measures may be biased by the rater's awareness and mood,[3,10–13] although at least for observer-report it has been shown that this bias is likely limited.[6,14] To provide a more protocolized assessment of cognition in the context of daily life, performance-based measures have been developed in which the participant or patient is required to complete a given task. Examples of performance-based measures of everyday functioning, targeting early changes, include the Harvard Automated Phone Task,[15,16] the Czaja Functional Assessment Battery,[17] and the Financial Capacity Instrument–Short Form.[18]

As digital tools such as smartphones have become an essential part of daily life, it seems logical to utilize them for the assessment of everyday functioning, particularly in individuals who already frequently use digital tools to perform various everyday tasks. Digital performance-based functional assessments could provide a low-cost, easily implementable, and ecologically valid measure of everyday functioning, that may yield valuable additional information over self- and observer-reported functioning. Yet, before digital assessments can be implemented, it is important to know whether they measure what they aim to measure, accurately reflect digital everyday tasks, and are accepted by users.

We developed and piloted a new, smartphone-based assessment for early functional changes in the context of early-stage AD: the Assessment of Smartphone Everyday Tasks (ASSET). The tasks included in ASSET were chosen to represent real-life healthcare-related activities that are commonly required of older adults, including refilling a medication prescription and scheduling an appointment with a care provider. ASSET was designed to be used as a clinically meaningful and reliable outcome measure for clinical trials in preclinical and prodromal AD stages as well as, ultimately, a screening tool in clinical settings.

In this study, we aimed to pilot ASSET in younger and older cognitively normal individuals, as well as individuals diagnosed with amnestic mild cognitive impairment (MCI). We included younger individuals because they are generally more intense users of smartphones than older individuals. We aimed to investigate ASSET's internal consistency by correlating the various ASSET tasks with each other, as well as to analyze ASSET's construct validity by correlating performance on ASSET with other functional assessments, cognitive performance, and demographics. We hypothesized that performance on ASSET would correlate more strongly with observer-reported than with self-reported everyday functioning. Furthermore, we expected to find a correlation with cognitive performance and age, but not with sex, education, or premorbid intelligence. Finally, we compared supervised and remote assessment, tested repeated assessment using alternate versions, and assessed usability of ASSET.

RESEARCH IN CONTEXT

1. **Systematic Review**: Digital assessment of everyday functioning in Alzheimer's disease is in its early days. We searched traditional channels (e.g., PubMed) for publications on digital assessment of instrumental activities of daily living in dementia and found less than a handful publications. As more tools become available, evidence is needed on their utility and user-friendliness.
2. **Interpretation**: This pilot study of the Assessment of Smartphone Everyday Tasks (ASSET) laid the foundation for evidence of ASSET's good psychometric properties. ASSET is a promising new digital performance-based assessment tool for the measurement of very early difficulty in performing complex everyday tasks, that may yield valuable information on cognition in everyday life.
3. **Future Directions**: ASSET should be offered to a larger, more diverse sample to replicate these findings. ASSET performance may also be linked to Alzheimer's disease biomarkers. Longer follow-up durations are also needed to determine ASSET's utility for the measurement of clinical progression.

2 | METHODS

2.1 | Participants

Recruitment occurred at the Center for Alzheimer Research and Treatment at the Brigham and Women's Hospital in Boston, Massachusetts, United States. Three groups of participants were included: young cognitively normal participants (YN; aged 18–30 years), older cognitively normal participants (CN; aged 60–90 years), and participants with MCI (aged 55–90 years). YN and CN participants were recruited through pamphlets and advertisements in local newspapers. MCI participants were referred after receiving a clinical diagnosis by their physicians affiliated with the memory disorder clinics of Brigham and Women's Hospital and Massachusetts General Hospital or recruited through the Massachusetts Alzheimer's Disease Research Center. YN participants were included to verify whether the application was acceptable for intense smartphones users and those who should be able to complete the tasks in ASSET with ease. As such, ASSET was first used by 10 YN participants before older adults were invited to use it. Cognitive status was confirmed for inclusion in the study based on the Mini-Mental State Examination (MMSE), Logical Memory subscale of the Wechsler Memory Scale – Revised, and the eight-item Informant Interview to Differentiate Aging and Dementia. Further inclusion criteria were having an available study partner (for CN and MCI participants) and being fluent in English. Exclusion criteria included the presence of a major psychiatric disorder, cerebrovascular disease, neurodegenerative disease (other than MCI), head injury with a prolonged loss of consciousness, or substance abuse.

2.2 | Materials and study procedures

2.2.1 | Assessment of Smartphone Everyday Tasks: ASSET

The ASSET application was developed for iOS and Android by the ADK Group in collaboration with investigators across Brigham and Women's Hospital, Massachusetts General Hospital, and the RAND Corporation. Over the course of 3 months, three AD experts (two behavioral neurologists and one neuropsychologist), one clinical informatics expert, and five medical application developers met six times. They first brainstormed ideas for clinically meaningful smartphone tasks for older adults to be included in ASSET. They then iteratively honed their ideas for the tasks, initially coming up with 18 potential tasks, which were then narrowed down to nine and expanded upon. Finally, they arrived at four tasks including several subtasks to make up ASSET and proceeded to develop them. Figure 1 shows a schematic overview, as well as screenshots, of ASSET's tasks and steps. ASSET includes two pre-tasks to assess motor speed and visual and tactile acuity, and general familiarity with using smartphone functions (Calculator and Phone Settings, respectively). Participants then answered questions about their smartphone use (determining what they use their smartphone for; how often they use their smartphone for tasks other than making a phone call; and how familiar they are with using their smartphone for tasks other than making a phone call).

The two main tasks of ASSET are the Patient Portal and Calendar. In the Patient Portal, participants completed several subtasks, including requesting a medication prescription refill, paying a hospital bill, scheduling an urgent appointment with a primary care physician, and scheduling a recurring appointment. The Calendar task consisted of adding the requested appointments to the calendar. Finally, participants were asked about how easy or difficult they thought using the application was.

A total of six versions of ASSET were created, each with differing details in the subtasks that were designed to be balanced in terms of length and complexity. ASSET was administered once in-clinic (version "A1"), and participants were then invited to complete ASSET an additional six times remotely from home on a biweekly schedule. The first remote assessment was the same version of ASSET (version "A2"); all subsequent remote assessments were the alternate versions "B"–"F", always administered in the same order.

After completion of the A1 and A2 assessments, participants were asked to rate various aspects of the usability of and their experience with ASSET. The questions were based on the System Usability Scale and the Usefulness, Satisfaction and Ease of use questionnaires,[19,20] and covered topics such as layout, clarity of instructions, ease of use, meaningfulness of tasks, and resemblance to other apps. All questions were rated on a 5-point Likert scale ranging from strongly disagree to strongly agree.

Assessments were pushed to the participants phone automatically at the scheduled intervals. Participants who missed an assessment were put back on the schedule unless they actively opted out of the study.

For each task, the number of correct responses were registered, as were the time it took to complete the subtask, and number of errors made. The main outcome for each task was the performance rate, which was determined by dividing the number of correct responses by the completion time, thus reflecting a duration-adjusted correct response rate. Performance rates could range from 0, indicating poor performance (i.e., longer time to complete and/or more mistakes), to 1, indicating excellent performance (i.e., shorter time to complete and/or fewer mistakes).

2.2.2 | Neuropsychological assessment

At their initial in-clinic visit, all participants underwent neuropsychological testing that included the MMSE,[21] the Wechsler Memory Scale – Revised Logical Memory task,[22] the Digit–Symbol Substitution Test,[23] the Free and Cued Selective Reminding Task,[24] and a verbal Category fluency task.[25] These measures were combined into the extended Preclinical Alzheimer's Cognitive Composite (PACC5).[26] PACC5 scores are centered around a sample mean of 0 with a standard deviation of 1, with higher scores indicating better cognitive functioning.

2.2.3 | Other measures

CN or MCI participants and their study partners completed the Cognitive Function Instrument (CFI) and Alzheimer's Disease Cooperative Study Activities of Daily Living – Prevention Instrument (ADCS ADL-PI). Depressive symptoms were assessed using the 30-item version of the Geriatric Depression Scale.[27] YN participants did not complete these additional questionnaires. Additional information about these measures is included in the Supplementary Material.

2.3 | Statistical analyses

All analyses were run in R version 4.3.0. Baseline differences between diagnostic groups were tested using Fisher's exact test or chi-squared test, as appropriate.

To assess discriminant validity, differences in baseline ASSET performance between diagnostic groups were tested by means of non-parametric Kruskal-Wallis test with the post-hoc Dunn test. Internal consistency of ASSET's Calendar and Patient Portal subtasks was assessed using Cronbach's alpha. Test–retest reliability was determined by intraclass correlation coefficients (ICCs) using a two-way

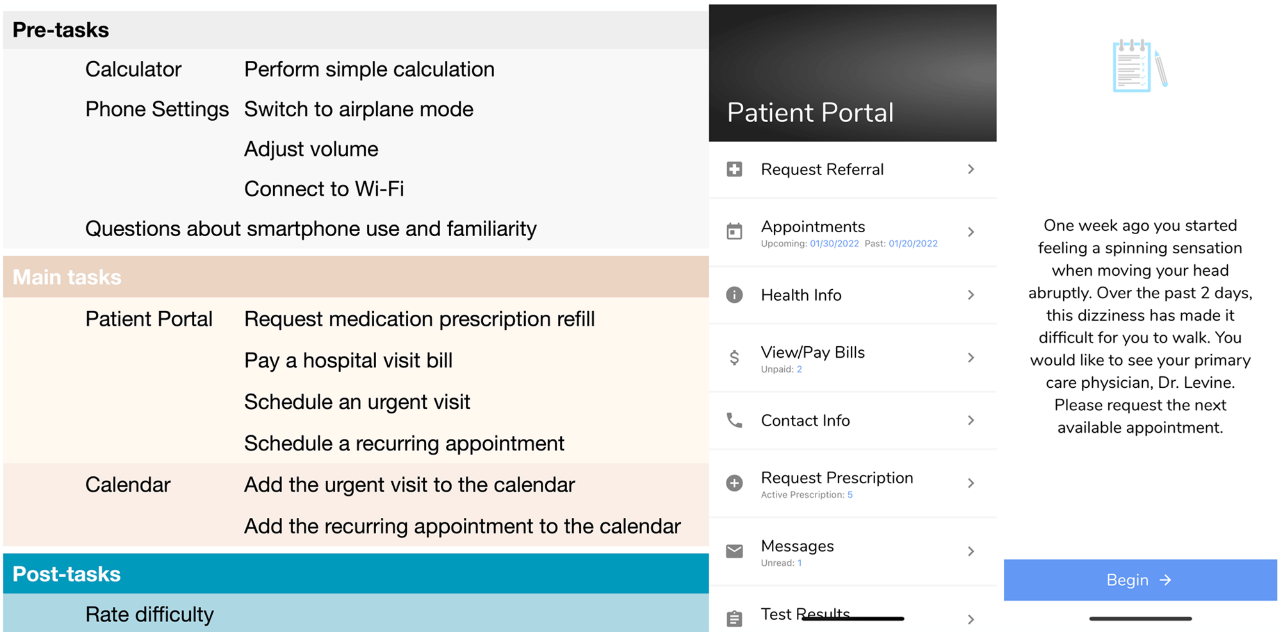

FIGURE 1 Assessment of Smartphone Everyday Tasks (ASSET) task and subtask overview (left), and screenshots of Patient Portal main screen (middle) and scheduling urgent appointment instructions (right).

random model of the absolute agreement type. Interpretation rules-of-thumb of Cronbach's alpha and ICCs are reported in the Supplementary Material.

Finally, in linear mixed models, change in performance over time was analyzed including random intercepts for each participant. MCI participants were excluded from these analyses, as only one individual completed all repeated assessments, and the others only completed between one and three assessments. Estimated marginal means and their 95% confidence intervals (95% CI) were computed from the linear mixed models to obtain assessment-specific estimates of the performance rates on ASSET's main tasks, both in the group as a whole and in the YN and CN groups separately.

3 | RESULTS

Forty-six participants (mean age 50.3 ± 27.1 years; 67% female) were included. Twenty (43.5%) were YN, 17 (37.0%) were CN, and 9 (19.6%) had MCI. Table 1 displays the demographics and characteristics of the participants.

Information about the participants' smartphone use is provided in the Supplementary Material.

3.1 | Initial assessment

The in-clinic assessment ("A1") was completed by all participants. On average, it took 12:12.9 minutes from start to end, including time spent reading instructions. YN participants took 7:21.8 minutes, CN participants took 15:08.4 minutes, and MCI participants took 15:24.8 minutes. Table 2 shows the average performance rates per subtask in the entire sample, as well as in each diagnostic group. In exploratory group comparisons, response rates of YN participants were higher than response rates of CN and MCI participants on all subtasks (all $p < 0.001$). There were no significant differences in response rates between CN and MCI participants (all $p > 0.05$). A detailed overview of rates, completion times, and number of errors per subtask is shown in Table S1.

Subtasks within the Patient Portal task showed acceptable internal consistency (Cronbach's alpha = 0.79, 95% CI = [0.67, 0.86]), as did subtasks within the Calendar task (Cronbach's alpha = 0.71, 95% CI = [0.42, 0.87]). The Patient Portal and Calendar tasks correlated strongly with each other (Pearson's $r = 0.75$, 95% CI = [0.58, 0.86], $p < 0.001$).

Patient Portal rates correlated significantly with study partner-reported everyday functioning ($r = 0.57$, $p = 0.002$), but not with self-reported everyday functioning ($r = 0.21$, $p = 0.322$), as measured on the ADCS ADL-PI across CN and MCI participants. Calendar rates correlated with neither study partner-reported ($r = 0.17$, $p = 0.430$), nor self-reported ADCS ADL-PI scores ($r = 0.21$, $p = 0.317$) across CN and MCI participants. Correlations with the CFI were similar to the ADCS ADL-PI. All correlation coefficients are displayed in Table 3.

Both Patient Portal ($r = 0.64$, $p < 0.001$) and Calendar rates ($r = 0.50$, $p < 0.001$) correlated positively with performance on the PACC5 across the whole sample (see Table 3). The correlation coefficients for Patient Portal rates were smaller in YN ($r = 0.56$, $p = 0.016$) and CN ($r = -0.01$, $p = 0.967$), but larger in MCI ($r = 0.82$, $p = 0.012$). Calendar rates were less strongly correlated with PACC5 in the different diagnostic groups (YN: $r = 0.46$, $p = 0.039$; CN: $r = 0.25$, $p = 0.340$; MCI: $r = 0.02$, $p = 0.964$).

TABLE 1 Participant demographics and characteristics

	Whole sample	Young normal (YN)	Old normal (CN)	Mild cognitive impairment (MCI)	*p*
N	46	20 (43.5)	17 (37.0)	9 (19.6)	
Age	50.3 ± 27.1	21.3 ± 2.6	74.6 ± 4.9	74.1 ± 5.2	<0.001
Female, *n* (%)	31 (67)	17 (85)	12 (70.6)	2 (22.2)	0.004
Education, *M* (IQR)	16 (14–18)	14.5 (13–15)	18 (16–18)	19 (18–20)	<0.001
Race, *n* (%)					0.024
White	37 (80.4)	11 (55.0)	17 (100.0)	9 (100.0)	
African American	2 (4.3)	2 (10.0)	0 (0.0)	0 (0.0)	
Asian	6 (13.0)	6 (30.0)	0 (0.0)	0 (0.0)	
Other	1 (2.2)	1 (5.0)	0 (0.0)	0 (0.0)	
Ethnicity, *n* (%)					0.325
Not Hispanic or Latino	38 (82.6)	14 (70.0)	15 (88.2)	9 (100.0)	
Hispanic or Latino	5 (10.9)	4 (20.0)	1 (5.9)	0 (0.0)	
Other/unknown	3 (6.5)	2 (10.0)	1 (5.9)	0 (0.0)	
AmNART VIQ	117.4 ± 17.9	109.5 ± 23.2	123.7 ± 7.2	123.9 ± 10.0	0.025
PACC5	0.06 ± 0.83	0.56 ± 0.42	0.15 ± 0.41	−1.37 ± 0.67	< 0.001
30-item GDS	4.6 ± 4.3	–	4.7 ± 4.7	4.4 ± 3.5	0.891
CFI					
Self	2.9 ± 2.4	–	2.0 ± 1.9	4.8 ± 2.1	0.004
Study partner	2.7 ± 3.4	–	0.9 ± 1.2	5.9 ± 3.9	< 0.001
ADCS ADL-PI					
Self	41.1 ± 4.4	–	42.2 ± 3.3	38.8 ± 5.6	0.060
Study partner	40.8 ± 4.7	–	43.2 ± 1.8	36.2 ± 5.1	< 0.001

Note: All data are displayed as mean ± standard deviation, except as stated otherwise.
Abbreviations: ADCS ADL-PI, Alzheimer's Disease Cooperative Study Activities of Daily Living – Prevention Instrument; AmNART, American National Adult Reading Test; CFI, Cognitive Function Instrument; CN; cognitively normal; GDS, Geriatric Depression Scale; IQR, interquartile range; M, median; MCI, mild cognitive impairment; PACC5, Preclinical Alzheimer's Cognitive Composite; VIQ, verbal intelligence quotient; YN, young normal.

TABLE 2 Performance rates on A1 assessment of ASSET, stratified by diagnostic group

	Whole sample	YN	CN	MCI	Difference
Pre-tasks					
Calculator	0.188 ± 0.124	0.290 ± 0.099	0.122 ± 0.076	0.088 ± 0.070	YN > CN, MCI
Phone Settings	0.179 ± 0.144	0.322 ± 0.112	0.102 ± 0.073	0.058 ± 0.031	YN > CN, MCI
Patient Portal	0.119 ± 0.065	0.184 ± 0.045	0.081 ± 0.028	0.062 ± 0.025	YN > CN, MCI
Calendar	0.014 ± 0.012	0.023 ± 0.013	0.008 ± 0.004	0.007 ± 0.004	YN > CN, MCI

Note: Displaying as mean ± standard deviation.
Abbreviations: ASSET, Assessment of Smartphone Everyday Tasks.

3.2 | Usability

Notably, most MCI participants were unable to complete ASSET remotely because they had difficulty performing the tasks. This led to all but one of them discontinuing their participation in this study. The results of the entire usability questionnaire are shown in the Supplementary Material.

3.3 | Repeated assessments

Participants were invited to complete ASSET remotely at a biweekly interval for a total of six times. The first remote assessment (A2) was identical to the in-clinic assessment (A1) and was used to determine test–retest reliability. The Patient Portal (ICC = 0.87, 95% CI = [0.77, 0.93]) showed good to excellent reliability and the Calendar

TABLE 3 Correlation coefficients between ASSET main tasks and other measures

Measure	Patient Portal	Calendar
Self-reported IADL[a]		
ADCS ADL–PI	0.21 [−0.21, 0.57]	0.21 [−0.21, 0.57]
CFI	−0.12 [−0.49, 0.29]	−0.03 [−0.42, 0.38]
Study partner-reported IADL[a]		
ADCS ADL–PI	0.57 [0.24, 0.79]	0.17 [−0.25, 0.53]
CFI	−0.42 [−0.70, −0.04]	−0.01 [−0.40, 0.39]
Cognition[b]		
PACC5	0.64 [0.42, 0.79]	0.50 [0.23, 0.69]

Note: All correlations shown as Pearson's r correlation coefficient [95% confidence interval].
Abbreviations: ADCS ADL–PI, Alzheimer's Disease Cooperative Study Activities of Daily Living – Prevention Instrument; ASSET, Assessment of Smartphone Everyday Tasks; CFI, Cognitive Function Instrument; IADL, instrumental activities of daily living; PACC5, Preclinical Alzheimer's Cognitive Composite.
[a]Across CN and MCI participants only.
[b]Across whole sample.

TABLE 4 ASSET performance rates by version

	Whole group	YN	CN
Patient Portal			
A1	0.139 [0.113, 0.166]	0.187 [0.164, 0.210]	0.081 [0.057, 0.105]
A2	0.150 [0.123, 0.176]	0.198 [0.176, 0.220]	0.094 [0.070, 0.119]
B	0.191 [0.164, 0.218]	0.253 [0.230, 0.275]	0.117 [0.092, 0.142]
C	0.183 [0.156, 0.210]	0.239 [0.217, 0.262]	0.116 [0.091, 0.142]
D	0.186 [0.159, 0.213]	0.246 [0.224, 0.269]	0.113 [0.087, 0.139]
E	0.190 [0.163, 0.218]	0.247 [0.224, 0.270]	0.120 [0.094, 0.147]
F	0.235 [0.208, 0.262]	0.305 [0.282, 0.328]	0.145 [0.117, 0.172]
Calendar			
A1	0.016 [0.011, 0.021]	0.022 [0.017, 0.028]	0.008 [0.002, 0.014]
A2	0.020 [0.015, 0.026]	0.029 [0.023, 0.035]	0.010 [0.004, 0.016]
B	0.022 [0.016, 0.027]	0.032 [0.026, 0.037]	0.010 [0.004, 0.016]
C	0.025 [0.020, 0.031]	0.036 [0.030, 0.041]	0.012 [0.006, 0.019]
D	0.032 [0.027, 0.038]	0.043 [0.038, 0.049]	0.018 [0.012, 0.024]
E	0.028 [0.023, 0.034]	0.040 [0.034, 0.046]	0.014 [0.007, 0.020]
f[a]	–	–	–

Note: Data shown as estimate [95% confidence interval].
Abbreviations: ASSET, Assessment of Smartphone Everyday Tasks; CN, old normal; YN, young normal.
[a]Data treated as missing due to technical error.

(ICC = 0.86, 95% CI = [0.63, 0.93]) showed moderate to excellent reliability.

MCI participants were not included in the analyses of repeated assessments. Performance on the Patient Portal task improved with successive assessments, both among YN and CN participants. In all participants, performance rates of both tasks did not differ significantly between versions A1 and A2, as evidenced by overlapping confidence intervals (see Table 4). Compared to versions A1 and A2, YN participants performed better on all subsequent assessments on both Patient Portal and Calendar. CN participants performed better on the Patient Portal task on versions B through F, but only performance of the version D Calendar task was statistically better than preceding assessments. Performance rate trajectories over repeated assessments are displayed in Table 4 and visually represented in Figure 2.

4 | DISCUSSION

Here, we present the new Assessment of Smartphone Everyday Tasks (ASSET) application that was developed as a performance-based

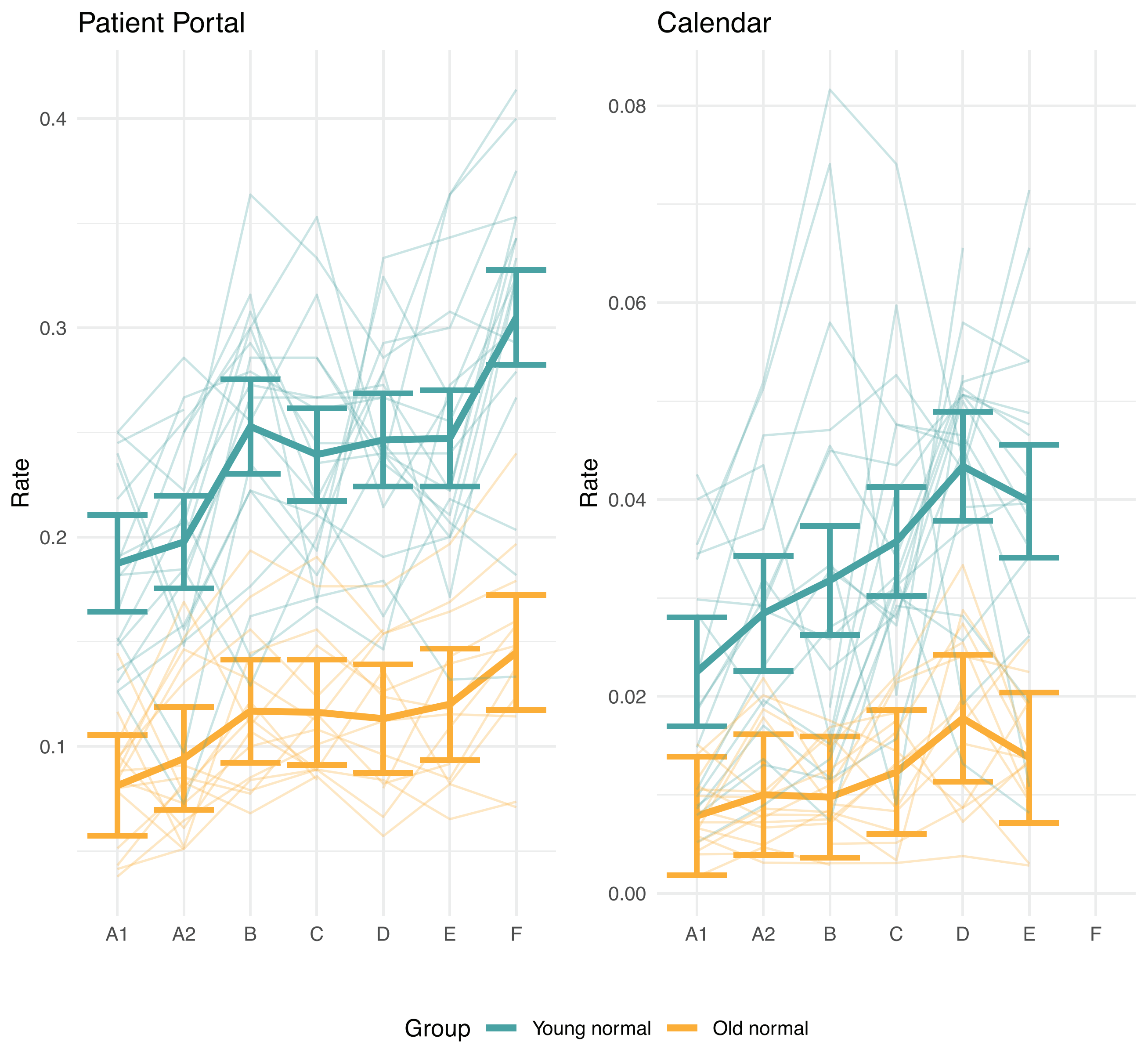

FIGURE 2 Patient Portal (left) and Calendar (right) performance rates over repeated assessments with versions A–F, separate by diagnostic group.*Note*: Due to a technical error, correct responses on the Calendar task in the F assessment were labeled as incorrect. We were unable to recover reliable performance rate data for this task and, therefore, treated these data as missing.

measure of everyday functioning to be used in older adults with or without memory complaints and those with early-stage (preclinical) AD. ASSET may be downloaded onto a personal device and provides a brief, unsupervised assessment of everyday functioning. In this study, we demonstrated that ASSET has a good internal consistency and good test–retest reliability. Further, we showed that scores improved over a 14-week period with biweekly repeated assessments in younger and older cognitively normal adults. Participants generally rated their experience with ASSET as neutral or positive.

Assessment of everyday functioning is a crucial element of the diagnostic workup for dementia. With advancements in diagnostic procedures, it has become increasingly easier to determine presence of AD pathology in early disease stages. This warrants the development of instruments that can reliably detect early changes in everyday functioning prior to the stage of dementia or mild cognitive impairment. When impairments in everyday functioning are minimal, performance-based measures can be used to obtain assessment of everyday functioning that is minimally impacted by rater bias. Performance-based instruments come in different shapes and sizes, although it should be noted that the psychometric properties of many of these have been insufficiently investigated.[28] Digital applications that can be downloaded onto someone's personal device have the potential to provide a practical and low-cost measure of everyday functioning.

ASSET was developed for iOS and Android and was designed to resemble patient portal and calendar smartphone applications. ASSET was not intended to measure general everyday functioning, but rather to assess specific healthcare-related IADL that are required of older adults and are increasingly commonly performed using smartphone applications. The tasks in ASSET were divided into two main tasks, Patient Portal and Calendar, that comprised four and two subtasks, respectively. We determined that both tasks had good internal consistency, thus justifying the use of a summarized performance rate over the subtasks. The two main tasks also correlated strongly with each other, suggesting that they tap into similar abilities. However, one task focused on healthcare-related activities while the other was more general. We, therefore, reported their scores separately.

We observed a moderate relationship between the Patient Portal task and two study partner-reported measures of everyday functioning in cognitively normal and mildly impaired older adults. This suggests that ASSET measures a construct that overlaps with study partner-reported everyday functioning. The relationship with self-reported everyday functioning was not as evident. A potential explanation for this finding is that subjective, self-perceived everyday functioning is not interchangeable with performance-based or study partner-reported everyday functioning. Differences between self- and study partner-reported everyday functioning have been described before,[4,29] and a previous study also found that performance-based assessment of everyday functioning correlated more strongly with study partner-report than self-report.[30] It may also mean that ASSET measures a different aspect of everyday functioning, that is more reflective of the cognitive performance of the tasks, rather than the experience of difficulties in everyday life.

The finding that, across all diagnostic groups, performance on ASSET correlated with cognitive performance seems to support the idea that ASSET measures cognitive functioning in an everyday life context. While there was no correlation between performance on the Patient Portal task and cognition in CN participants alone, this association did exist in YN and MCI participants. Conceptually, everyday functioning relies on cognition and therefore, it is noteworthy that the relationship we observed is less evident than expected. It is possible that the relatively restricted range in performance on cognitive measures among individuals who are cognitively unimpaired reduced the power to detect a relationship in this small sample.

A next step in our pilot study was to determine test–retest reliability. All participants initially completed ASSET at their baseline in-clinic visit. The same version of ASSET was then pushed to the participant's personal device 2 weeks later, a time period over which no substantial change in performance is expected. Of note, the second assessment was completed remotely and unsupervised at home by the participants. The Calendar task showed moderate to excellent, and the Patient Portal task showed good to excellent test–retest reliability. Therefore, performance on the first two assessments with ASSET seemed stable. Additionally, there did not appear to be a significant difference between completion of the assessment in the research clinic versus remotely at home, which is a desirable property of this test in terms of increasing accessibility for wider spread use.

Practice effects seemed to exist over repeated assessments during a 3-month period in which participants completed six parallel versions of ASSET on a biweekly schedule. This appears to further speak to the argument that ASSET is a cognitive test in a daily life setting. Among YN and CN participants, ASSET performance gradually increased over repeated completions of the tasks. The increase in performance was more pronounced in YN participants and stronger on the Patient Portal than on the Calendar. This increase in performance appears to reflect a practice effect. Practice effects have been described for cognitive assessments as a potentially valuable source of information about early cognitive changes in the context of AD.[31,32] Studies have associated reduced practice effects with MCI or AD dementia diagnosis, AD risk factors, and risk of future cognitive decline.[32] It would be interesting to investigate in the future whether practice effects on ASSET are diminished in those with underlying AD pathology.

ASSET was designed to be particularly challenging, to elicit subtle difficulties in everyday functioning. Notably, most MCI participants were unable to use ASSET at home without supervision of study personnel. They reported getting confused about getting into the app, experiencing difficulties completing the tasks—especially the Patient Portal tasks containing many little details to remember—, and therefore dropped out of this part of the study. The inability of these participants to complete ASSET remotely implies that the tasks were too complicated for them to complete independently. In both clinical practice and research, it is essential to consider what outcome measure to use for the target population. While it did not occur in this pilot study, should a participant be unable to complete ASSET's pre-tasks, this should be taken as a sign that ASSET might not be a suitable instrument to assess their everyday functioning. Based on these findings, we believe ASSET may be most suitable for individuals who have not yet reached objective cognitive impairment.

Finally, we surveyed user experiences of ASSET concerning various aspects of using the application, including ease of use, design and layout, and meaningfulness of tasks. Overall, participants rated ASSET neutrally or positively. Most considered the layout appropriate, and more than half indicated that ASSET resembled other phone applications. YN participants rated all aspects more positively than CN and MCI participants, and it seemed that older individuals may find ASSET more difficult to navigate. Improvements to ASSET may still need to be made to make it easier to recover from mistakes, and potentially to make ASSET more fun to use, which might reduce the chances of discontinuation over repeated assessments. Organizing future focus groups or interviews with prospective users to probe user experiences and preferences more extensively will help to determine the aspects of ASSET that may need to be improved. This will help promote acceptance and ensure continued use of the application.

This study had several limitations. Because it is a pilot study, we were limited by a small sample size, particularly for the MCI group. Ethnoracial diversity was limited in the CN and MCI groups. Further, most participants were highly educated. Moreover, there is no equal access to digital tools around the world, and although this is improving, ASSET certainly will not be usable by everyone. This constrains generalizability to the broader population at risk for AD and related disorders. Important strengths of this study included the extensive clinical assessment performed at baseline, that allowed us to relate performance on ASSET to various other participant characteristics. Our study design included repeated assessments, which enabled us to do longitudinal analyses, as well as a comparison of in-clinic vs. remote use. Finally, we asked participants to rate their experience with ASSET in a standardized way, which is not always taken into consideration. In future studies, ASSET may be administered to a larger and more diverse group of individuals at risk for AD. Performance on ASSET should then also be linked to the AD biomarkers of amyloid and tau. Longer follow-up durations are also needed to determine ASSET's utility for the measurement of clinical progression.

We conclude that ASSET is a promising new performance-based assessment tool for the measurement of very early difficulty in performing complex everyday tasks. With the present study we provide the first evidence for ASSET's good reliability and validity, thus forming the basis for further investigation of the application's psychometric properties. Ultimately, ASSET may be used as a brief, low-cost, objective assessment of impairment in cognitive functioning in a daily-life setting to be used in conjunction with study partner- and self-reported outcome measures of broader everyday functioning.

ACKNOWLEDGMENTS

This work was supported by a grant from the NIH/NIA (R42 AG069629) and the Vettel Family and Polayes Family funds. We would also like to acknowledge the ADK Group, who was partner in the development of ASSET. M.A.D. received grant support from Alzheimer Nederland (WE.06-2023-02), paid to his institution. T.C.H., I.M.L., and K.J.M. report no relevant disclosures. S.A.M.S. research programs have been funded by ZonMW (#7330502051 and #73305095008) and Health~Holland, Topsector Life Sciences & Health (LSHM19051, LSHM20084, LSHM22026-SGF). S.A.M.S. provided consultancy services to Prothena Biosciences, Aribio, Cogstate, Biogen, Boehringer and Toyama. All funds are paid to her institution. S.H.F., D.M.R., R.A.S., K.V.P., and R.E.A. report no relevant disclosures. G.A.M. has received research salary support for serving as site principal investigator for clinical trials funded by Eisai Inc., Eli Lilly and Company, and Genentech. These relationships are not related to the content in the manuscript.

CONFLICT OF INTEREST STATEMENT

G.A.M. is a senior associate editor for this journal but was not involved in the journal's peer-review process nor had access to any information regarding its peer-review. The other authors report no conflicts of interest pertaining to this manuscript. Author disclosures are available in the supporting information.

CONSENT STATEMENT

This study was approved by the institutional review board of Partners Healthcare Inc. All participants provided written informed consent before participating in any study procedures.

ORCID

Mark A. Dubbelman https://orcid.org/0000-0002-5708-4925
Sietske A. M. Sikkes https://orcid.org/0000-0002-0161-3656
Kathryn V. Papp https://orcid.org/0000-0003-1687-4370

REFERENCES

1. Scheltens P. Alzheimer's disease. *Lancet North Am Ed*. 2021;397(10284):1577-1590.
2. Dubbelman MA, Jutten RJ, Tomaszewski Farias SE, et al. Decline in cognitively complex everyday activities accelerates along the Alzheimer's disease continuum. *Alzheimers Res Ther*. 2020;12(1):138.
3. Numbers K, Jang S, Brodaty H, et al. Instrumental activities of daily living by subjective and objective measures: the impact of depression and personality. *Front Aging Neurosci*. 2022;14:829544.
4. Verrijp M, Dubbelman MA, Visser LNC, et al. Everyday functioning in a community-based volunteer population: differences between participant- and study partner-report. *Front Aging Neurosci*. 2021;13:761932.
5. Jutten RJ, Peeters CFW, Leijdesdorff SMJ, et al. Detecting functional decline from normal aging to dementia: development and validation of a short version of the Amsterdam IADL Questionnaire. *Alzheimers Dement*. 2017;8:26-35.
6. Sikkes SAM, Knol DL, Pijnenburg YAL, et al. Validation of the Amsterdam IADL Questionnaire(c), a new tool to measure instrumental activities of daily living in dementia. *Neuroepidemiology*. 2013;41(1):35-41.
7. Dubbelman MA, Verrijp M, Terwee CB, et al. Pursuing clinical meaningfulness: determining the minimal important change of everyday functioning in dementia. *Neurology*. 2022:e954-e964.
8. Tomaszewski Farias S, Cahn-Weiner DA, Harvey DJ, et al. Longitudinal changes in memory and executive functioning are associated with longitudinal change in instrumental activities of daily living in older adults. *Clin Neuropsychol*. 2009;23(3):446-461.
9. Cloutier S, Chertkow H, Kergoat M-J, Gélinas I, Gauthier S, Belleville S. Trajectories of decline on instrumental activities of daily living prior to dementia in persons with mild cognitive impairment. *Int J Geriatr Psychiatry*. 2021;36(2):314-323.
10. Okonkwo OC, Griffith HR, Vance DE, Marson DC, Ball KK, Wadley VG. Awareness of functional difficulties in mild cognitive impairment: a multidomain assessment approach. *J Am Geriatr Soc*. 2009;57(6):978-984.
11. Ready RE, Ott BR, Grace J. Validity of informant reports about AD and MCI patients' memory. *Alzheimer Dis Assoc Disord*. 2004;18(1):11-16.
12. Persson K, Brækhus A, Selbæk G, Kirkevold Ø, Engedal K. Burden of care and patient's neuropsychiatric symptoms influence carer's evaluation of cognitive impairment. *Dement Geriatr Cogn Disord*. 2015;40(5-6):256-267.
13. Nosheny RL, Amariglio R, Sikkes SAM, et al. The role of dyadic cognitive report and subjective cognitive decline in early ADRD clinical research and trials: current knowledge, gaps, and recommendations. *Alzheimers Dement*. 2022;8(1):e12357.
14. Dubbelman MA, Verrijp M, Facal D, et al. The influence of diversity on the measurement of functional impairment: an international validation of the Amsterdam IADL Questionnaire in eight countries. *Alzheimers Dement*. 2020;12(1):e12021.
15. Marshall GA, Dekhtyar M, Bruno JM, et al. The Harvard Automated Phone Task: new performance-based activities of daily living tests for early Alzheimer's disease. *J Prev Alzheimers Dis*. 2015;2(4):242-253.
16. Marshall GA, Aghjayan SL, Dekhtyar M, et al. Activities of daily living measured by the Harvard Automated Phone Task track with cognitive decline over time in non-demented elderly. *J Prev Alzheimers Dis*. 2017;4(2):81-86.
17. Czaja SJ, Loewenstein DA, Sabbag SA, Curiel RE, Crocco E, Harvey PD. A novel method for direct assessment of everyday competence among older adults. *J Alzheimers Dis*. 2017;57(4):1229-1238.
18. Gerstenecker A, Eakin A, Triebel K, et al. Age and education corrected older adult normative data for a short form version of the Financial Capacity Instrument. *Psychol Assess*. 2016;28(6):737-749.
19. Lund AM. Measuring usability with the USE questionnaire. *Usability Interface*. 2001;8(2):3-6.

20. Lewis JR. The System Usability Scale: past, present, and future. *Int J Human–Comput Interact*. 2018;34(7):577-590.
21. Folstein MF, Folstein SE, Mchugh PR. "Mini-mental state": a practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res*. 1975;12(3):189-198.
22. Wechsler D, Stone CP. *Wechsler Memory Scale-Revised*. Psychological Corporation; 1987.
23. Wechsler D. *WAIS-R Manual: Wechsler Adult Intelligence Scale-Revised*. Psychological Corporation; 1981.
24. Grober E, Ocepek-Welikson K, Teresi JA. The free and cued selective reminding test: evidence of psychometric adequacy. *Psychol Sci Q*. 2009;51:266-282.
25. Monsch AU, Bondi MW, Butters N, Salmon DP, Katzman R, Thal LJ. Comparisons of verbal fluency tasks in the detection of dementia of the Alzheimer type. *Arch Neurol*. 1992;49(12):1253-1258.
26. Papp KV, Rentz DM, Orlovsky I, Sperling RA, Mormino EC. Optimizing the preclinical Alzheimer's cognitive composite with semantic processing: the PACC5. *Alzheimers Dement*. 2017;3(4):668-677.
27. Yesavage JA, Brink TL, Rose TL, et al. Development and validation of a geriatric depression screening scale: a preliminary report. *J Psychiatr Res*. 1982;17(1):37-49.
28. Wesson J, Clemson L, Brodaty H, Reppermund S. Estimating functional cognition in older adults using observational assessments of task performance in complex everyday activities: a systematic review and evaluation of measurement properties. *Neurosci Biobehav Rev*. 2016;68:335-360.
29. Farias ST, Mungas D, Jagust W. Degree of discrepancy between self and other-reported everyday functioning by cognitive status: dementia, mild cognitive impairment, and healthy elders. *Int J Geriatr Psychiatry*. 2005;20(9):827-834.
30. Marshall GA, Aghjayan SL, Dekhtyar M, et al. Measuring instrumental activities of daily living in non-demented elderly: a comparison of the new performance-based Harvard Automated Phone Task with other functional assessments. *Alzheimers Res Ther*. 2019;11(1):4.
31. Jutten RJ, Rentz DM, Fu JF, et al. Monthly at-home computerized cognitive testing to detect diminished practice effects in preclinical Alzheimer's disease. *Front Aging Neurosci*. 2021;13:800126.
32. Jutten RJ, Grandoit E, Foldi NS, et al. Lower practice effects as a marker of cognitive performance and dementia risk: a literature review. *Alzheimers Dement*. 2020;12(1):e12055.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Dubbelman MA, Hall TC, Levesque IM, et al. Using a digital tool to detect early changes in everyday functioning in older adults: A pilot study of the Assessment of Smartphone Everyday Tasks (ASSET). *Alzheimer's Dement*. 2023;15:e12506. https://doi.org/10.1002/dad2.12506