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Original Article

Feasibility of computerized motor, cognitive and speech tests in the home: Analysis of TAS Test in 2,300 older adults

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ABSTRACT

Background: Early detection of Alzheimer's disease (AD) risk is crucial for dementia prevention. Tasmanian Test (TAS Test) is a novel, unsupervised, computerized assessment of motor, cognitive, and speech function designed to detect AD risk.
Objectives: To evaluate the feasibility, usability, and acceptability of TAS Test.
Design and setting: TAS Test was administered remotely at home and/or in a research facility, using personal computers.
Participants: 2,351 adults aged 50–89 years (mean 65.35), 71.76 % female, from Tasmania, Australia.
Measurements: Completion rates, ease-of-use, distraction, test duration, and enjoyment scores. Demographics, computer literacy, cognition, and mood were analyzed.
Results: Over 80 % completed motor and cognitive components with 92.8 % completing speech tests. 89.81 % found the duration acceptable. 80.90 % of remote and 83.46 % of onsite participants enjoyed the procedure. High usability and acceptability were reported, with age, gender, education, computer literacy, cognition and mood having minimal or no impact.
Conclusions: TAS Test demonstrated high completion rates and user satisfaction across a large community sample, supporting its feasibility as an unsupervised computerized assessment tool. Future research should address demographic representation and technical refinements.

1. Introduction

Dementia is considered the greatest global challenge in health and social care of this century [1] and prevalence is rapidly rising [2]. The World Health Organization (WHO) has prioritized dementia prevention as a key public health strategy [3] as research suggests up to 45 % of dementia cases could be prevented, or delayed, by addressing modifiable risk factors [1,2]. However, a fundamental unmet need is the development of a low-cost population-level screening method so risk reduction interventions can be targeted at people with higher dementia risk before cognitive impairment develops.

Alzheimer's disease (AD) is the most common cause of dementia and has a 10–20-year preclinical stage, with insidious accumulation of amyloid and tau proteins in the brain, before cognitive symptoms emerge [4,5]. This preclinical phase represents a critical window of opportunity for risk modification and a population-level tool that detects this stage would transform the effectiveness of dementia prevention. While positron emission tomography (PET) brain scans, and blood-based and cerebrospinal fluid (CSF) tests can measure AD pathology, including in preclinical AD, their invasiveness, specialization, and cost render them unsuitable for population-level screening [6–9].

TAS Test (or 'Tasmanian Test'), a novel 20-minute online platform of motor-cognitive-speech tests has been designed in Tasmania (the island State of Australia) to be completed unsupervised in individuals' homes. The TAS Test protocol and rationale has previously been described in detail by Alty et al. [10]. The protocol, described in [10,11], builds upon a new body of research that found hand movements, as well as speech features and cognitive performance, subtly change in the earliest

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stages of the AD continuum and these fine changes can be measured precisely with Artificial Intelligence (AI) based computer techniques [12–15]. TAS Test has been purposefully designed for real-life home environments as it collects data through ubiquitous computer equipment such as keyboards and webcams [16,17]. Furthermore, the TAS Test algorithms for analyzing hand movements in digital video data have been validated against wearable sensors [18] and state-of-the-art deep learning motion tracking [19] and designed to be accurate despite cluttered backgrounds, low lighting, and low-quality cameras [20,21].

TAS Test also includes computerized cognitive and speech tests based on principles from other neuropsychological tests; this facilitates the exploration of motor-cognitive-speech associations and the development of 'multimodal' predictive algorithms. The emerging field of multimodal AI integrates and processes information stemming from diverse 'modalities' [22], which refer to manifold data such as text, video, and audio data. In neurodegenerative disease research, this new AI approach has demonstrated improved accuracy of predictive algorithms compared to using single modalities and provides rich insights into early functional 'signatures' of disease subtypes [23,24].

A population-level test ideally needs to be administered remotely and unsupervised. Computerized screening tests have wide reach given the accessibility of computer devices in the home and community centers (e.g. libraries, leisure centers, clinics); for example, 82 % of households have internet-accessible devices [25] including 89 % of Australians over 50 years old [26]. Secondly, computerized tests allow for automated and more precise scoring, allowing for time and cost efficiency [27]. Previous unsupervised web-based cognitive tests, such as CANTAB and Cogstate, have been successfully employed at home [13] but do not offer a multimodal approach.

The aim of this study was to evaluate the feasibility, usability and acceptability of TAS Test in a community cohort of older adults. Feasibility analysis would provide insight into the practicality. Our initial validation analyses found that the TAS Test motor function tasks improve estimation of proxy measures of AD risk (lower episodic memory scores) in cognitively asymptomatic older adults [28,29]. Evaluating the usability of TAS Test would determine whether it is intuitive and accessible to individuals with varying levels of technological proficiency and could improve further iterations of the tool. Understanding participant engagement and satisfaction through acceptability assessments is crucial for fostering widespread adoption and adherence. For feasibility, we hypothesized that participants would be able to follow instructions and successfully complete TAS Test without significant difficulty or issues. For usability, we hypothesized that participants would find it is easy to use with minimum distraction. For acceptability, we hypothesized that participants would find TAS Test engaging, leading to positive enjoyment ratings of the procedures.

2. Methods

2.1. Study participants

Participants were aged 50 years and older and living in Tasmania, Australia. They were recruited from a community sample of adults who were enrolled in the Island Study Linking Aging and Neurodegenerative Disease (ISLAND) Project [30,31]; this 10-year public health initiative aims to reduce modifiable dementia risk factors via online education and personalized feedback [31]. ISLAND participants who had completed their annual health surveys were invited to take part in the TAS Test substudy. Participants voluntarily chose whether to complete TAS Test at home, in the research center, or both, based on their personal preference and convenience.

2.2. Ethics and consent

The University of Tasmania Human Research Ethics Committee (HREC) approved the TAS Test Project (HREC reference H0021660; registered as NCT05194787 on the ClinicalTrials.gov registry) and the ISLAND Project (HREC reference H001864). Participants gave informed consent, and all procedures were carried out in accordance with the National Health and Medical Research Council's National Statement on Ethical Conduct in Human Research and the Declaration of Helsinki.

2.3. TAS Test website overview

The TAS Test protocol and rationale has previously been described in detail by Alty et al. [10]; in brief, it begins with standardized instructions for correct positioning, including placing the hands about 50 cm distance from the webcam and maintaining a stable seated position. There are green boxes on the computer screen for video-recorded tasks to help guide the participant to correctly position their hands. Participants are asked to confirm consent for video and audio-based assessments and can opt out of video/audio components of the protocol if they do not have this equipment or prefer not to be video-/audio-recorded. Tests are participant-paced, allowing pausing and exiting (as well as resuming at a different time or day), with all interactions time-stamped. There are five main sections to TAS Test: video hand movement tests, keyboard hand movement tests, visuomotor tests, visual and spatial working memory tests, and speech tests. All participants complete the same fixed protocol of tasks in TAS Test; the only discontinue rule occurs with the Sequence Span Test, where two consecutive mistakes result in discontinuation of the task.

2.4. Multimodal TAS Test data collection

2.4.1. Video hand movement tests

TAS Test comprises 12 video-recorded hand movement tasks, including finger tapping and other standardized motor assessments. Each task begins with a looped instructional video and written instructions followed by a screen that video-records for 10–30 ss using the computer webcam [17]. The video capture maintains a consistent frame rate (30 fps) across different systems, and TAS Test automatically adjusts for variations in video quality [18,21]. The range of tasks include fast tapping the index finger against the thumb– completed with each hand separately, for 10 ss each, and then together, first in phase and then out of phase [11]. Other tasks include counting back from 100 whilst finger tapping (i.e. a dual motor-cognitive task). The software provides both video and text guidance for standardized positioning of the participant's hands at the start of each task [18]. As with any remote computerized assessment, there will naturally be some variation in participant positioning and setup. To account for this, the measurements extracted from the digital video are performed offline using validated computer vision algorithms that focus primarily on temporal features and relative changes in movement patterns rather than absolute spatial measurements [20,21].

2.4.2. Keyboard hand movement tests

Participants complete a series of keyboard-based hand movement assessments, such as tapping the spacebar as fast as possible, tapping adjacent keys in specific 2-key or 3-key sequences and tapping keys that are widely spaced apart on the keyboard. Each test begins with an instruction screen followed by a recording screen; hand movements are recorded for 10–30 ss with fixed 30-second rest intervals in between [28]. To account for variations in keyboard hardware across different computers, our analysis focuses on relative changes in performance patterns (such as rhythm and variability) rather than absolute speeds. This approach, validated in previous work [28], helps ensure that measured differences reflect true variations in motor-cognitive performance rather than hardware differences.

2.4.3. Visuomotor Tests

TAS Test comprises two visuomotor tests: an adapted version of the Cats-and-Dogs test [32] and a Reaction Time Test. In the Cats-and-Dogs

test, participants are presented with a series of images, each depicting either a cat or a dog, with some skewed at an angle. Each image is displayed for 450 milliseconds, after which a choice screen appears, prompting participants to specify whether it portrayed a cat or a dog.

The Reaction Time test comprises two distinct components: single-choice and 5-choice reaction time tests, which differ from the repetitive motor tasks (video finger tapping and keyboard tapping) by requiring specific responses to visual stimuli rather than continuous movement patterns.

2.4.4. Visual and spatial working memory tests

The TAS Test Complex Figure Test is adapted from the Benson Figure [33] which serves as a simplified variant of the Rey-Osterrieth complex figure. During the initial viewing phase, participants are presented with the complex image and given up to 1 min to memorize it before proceeding to complete a different task (the Spatial Span test). During the recognition phase, participants are presented with 20 sub-sections of the Benson Figure in a random order, including both components that were part of the original figure and distractor items that were not. Participants must respond 'YES' or 'NO' for each sub-section.

The Spatial Span test encompasses practice, and test phases and is based on the Corsi Block-Tapping Task [34]. Participants are instructed to memorize and replicate sequences of colored circles displayed on the screen, starting with 2 circles and progressing to lengthen the sequence by one extra circle each time the participant successfully remembers the sequence – up to a maximum of a 9-circle sequence.

2.4.5. Speech Test

TAS Test captures a diverse range of speech characteristics. In the standardized picture description task, participants are presented with the 'Cookie Theft' picture [35] and asked to describe the scene it portrays. Responses are recorded using the computer microphone. Participants' verbal responses are digitally recorded and processed through custom software algorithms to evaluate various aspects of linguistic competence, including lexical, pragmatic, semantic, and syntactic features.

2.4.6. TAS Test feedback questionnaire

At the completion of TAS Test, participants were invited to complete an optional questionnaire that was presented on the screen. The following questions were asked, with the response options outlined in parentheses:

1. What level of computer literacy do you have? (0–5, where 0 indicated very limited computer skills and 5 represented advanced computer proficiency)
2. How helpful were the video instructions to guide you to complete the test? (0–5, where 0 indicated 'not helpful at all' and 5 indicated 'very helpful')
3. How helpful were the text instructions to guide you to complete the test? (0–5, where 0 indicated 'not helpful at all' and 5 indicated 'very helpful')
4. Did you enjoy the testing procedure? (Yes/No)
5. How satisfied are you with the ease of use of this software? (0–5, where 0 indicated 'very dissatisfied' and 5 indicated 'very satisfied').
6. Were you distracted at any time during testing? (Yes/No)
7. Were you able to follow the instructions easily? (Yes/No)
8. Did you feel you had the appropriate hardware (keyboard, mouse, computer) to participate in the test? (Yes/No)
9. Was the test too long/too short/ about right? (Too long, Too short, About right)

2.5. Demographic data

As part of the broader ISLAND Project, participants complete annual surveys on dementia risk behaviors, medications, and general health, as well as covariates including age, sex, education level, depression, and anxiety levels (measured through the Hospital Anxiety and Depression Scale [HADS]) [36]. Every two years ISLAND participants also complete the Cambridge Neuropsychological Test Automated Battery (CANTAB) Paired Associates Learning (PAL) and Spatial Working Memory (SWM) tasks that assess visual episodic memory and working memory/executive function respectively [37]. This pre-existing data from the ISLAND project allowed for exploration of how demographic characteristics, cognitive performance, and mood may associate with TAS Test user-experience responses.

2.6. Data analysis

Pearson correlation coefficients (r) were calculated to assess the strength and direction of the linear relationship between two continuous variables [38] such as age, computer literacy, cognitive function, depression, and anxiety, with usability and acceptability metrics of TAS Test. The p-value associated with each correlation coefficient was calculated using standard statistical methods. Mann-Whitney U tests were used to compare ease-of-use scores between different participant groups (e.g., those reporting low vs high ease-of-use scores) due to the non-normal distribution of these variables. Mean values (M) were calculated to summarize the central tendency of continuous variables, such as ease-of-use scores, and completion rates across different demographic groups or test conditions. Standard deviations (SD) were also computed to quantify the dispersion of data around the mean.

3. Results

In total, 2351 participants were recruited. Out of these, Group 1 comprised 386 participants who completed TAS Test first in the research center (January to May 2021) and then completed it a second time at home (July to September 2021); Group 2 comprised 1790 participants who completed TAS Test just once, at home, and Group 3 comprised 175 participants who completed TAS Test first at home (July to September 2021), and a second time in the research center (October 2021); see Fig. 1

3.1. Demographics

Table 1 summarizes the demographic details of the participants. The mean (SD) age was 65.35 (7.51) years and 71.76 % were female. The majority had normal scores on validated measures of depression, anxiety and cognition. The group mean score for computer literacy was 3.74 on a scale of 1–5.

3.2. Feasibility

There were high completion rates for each test with more than 81 % of participants completing the keyboard-tapping hand motor tasks and cognitive tests and 92.8 % completing the speech tests. 66.3 % of participants completed all tests.

The completion rates varied across groups. In Group 1 (n = 386), the completion rate went from 97 % in the research facility to 83.8 % in the home. In Group 3 (n = 175), the completion rate went from 61.5 % in the home to 97 % in the research facility. For Group 2 (n = 1790) who only completed TAS Test once at home, the completion rate was 61.5 %.

Only 10.6 % of users reported not having appropriate computer hardware to complete component tasks of TAS Test. Of those who completed all tasks and the questionnaire, the mean (SD) time taken to complete TAS Test was 42.43 (14.70) minutes. We excluded users' data that had a completion time exceeding two hours (n = 179) or less than 15 mins (n = 48), assuming such data to either reflect significant interruptions during data collection and random responses respectively.

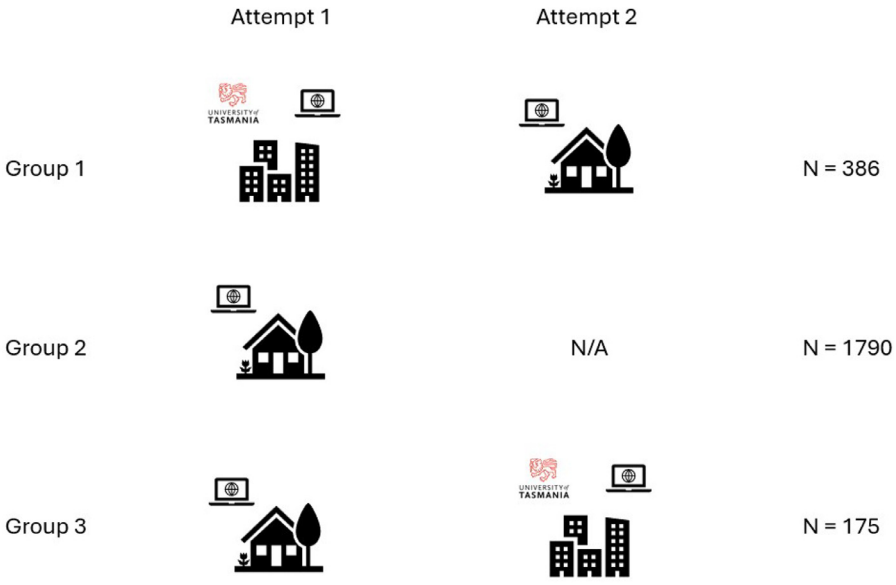

Fig. 1. Schematic overview demonstrating the number of participants who completed TAS Test and the location of their first and second attempts, where the house and university icons denote home and in the research facility respectively.

Table 1
Summary of demographics by group.

Demographic	Total (n = 2351)	Group 1 (n = 386)	Group 2 (n = 1790)	Group 3 (n = 175)
Age	65.35 (7.51)	64.9 (7.4)	65.5 (7.6)	64.8 (7.3)
Mean (SD)				
Median [Min, Max]	65.0	64.0	65.0	64.0
	[50.0, 89.0]	[50.0, 86.0]	[50.0, 89.0]	[51.0, 85.0]
Gender; n (%)	1687 (71.76)	277 (71.76)	1285 (71.79)	125 (71.43)
Female				
Male	661 (28.12)	109 (28.24)	503 (28.10)	49 (28.00)
Other	2 (0.09)	0 (0.00)	1 (0.06)	1 (0.57)
Prefer not to say	1 (0.04)	0 (0.00)	1 (0.06)	0 (0.00)
Highest Education Level; n (%)	844 (35.62)	138 (35.75)	638 (35.64)	68 (38.86)
Higher University degree				
Bachelor's degree	516 (21.95)	85 (22.02)	392 (21.90)	39 (22.29)
Diploma/associate degree	461 (19.62)	75 (19.43)	354 (19.78)	32 (18.29)
High School	252 (10.72)	41 (10.62)	192 (10.73)	19 (10.86)
Certificate/Apprenticeship	232 (9.87)	38 (9.84)	177 (9.89)	17 (9.71)
Other	46 (1.96)	9 (2.33)	37 (2.07)	0 (0.00)
Computer literacy (1–5)	3.74 (0.93)	3.82 (0.90)	3.72 (0.94)	3.78 (0.91)
Mean (SD)				
Anxiety; n (%)	1980 (84.22)	325 (84.20)	1508 (84.25)	147 (84.00)
Normal				
Borderline abnormal	212 (9.02)	35 (9.07)	161 (8.99)	16 (9.14)
Abnormal	159 (6.76)	26 (6.74)	121 (6.76)	12 (6.86)
Depression; n (%)	2171 (92.34)	357 (92.49)	1652 (92.29)	162 (92.57)
Normal				
Borderline abnormal	127 (5.40)	20 (5.18)	97 (5.42)	10 (5.71)
Abnormal	53 (2.25)	9 (2.33)	41 (2.29)	3 (1.71)
Cognitive function; Mean (SD)	−0.3 (1.1)	−0.29 (1.08)	−0.31 (1.11)	−0.28 (1.07)
PAL				
SWM	0.2 (0.9)	0.21 (0.89)	0.19 (0.90)	0.22 (0.88)

Note: PAL, Paired Associates Learning; SWM, Spatial Working Memory. PAL and SWM scores are presented as Z-scores normalized to age-matched controls, where 0 represents the population mean, and scores of ±1 represent one standard deviation above/below the mean.

3.3. Usability

Participants generally reported that TAS Test was easy to use, whether completed at home (remote) or at the research facility (onsite). The data presented in Table 2 illustrate usability metrics split by site and by attempt, respectively. The mean (SD) ease-of-use scores, out of a maximum of 5, were 4.21 (0.90) at home and 4.08 (0.92) at the research facility. Most participants (87.36 % remote, 72.00 % onsite) reported that instructions were easy to follow. Video and text instructions were both considered helpful with mean (SD) scores of 4.50 (0.85) and 4.30 (0.93), out of 5, respectively. Reports of feeling distracted during TAS Test were relatively low for both groups, with fewer participants at home feeling distracted than at the research facility. Generally, participants reported slightly higher scores for usability on the second attempt.

3.4. Acceptability

Most participants stated that they enjoyed the TAS Test procedure, and this was similar for attempts at home (80.90 %) and at the research facility (83.46 %). Regarding duration, 89.81 % found the test length

Table 2
Comparison of usability metrics by test site and attempt.

	By Test Site		By Attempt	
Metric	Remote	Onsite	First	Second
Number of Participants	1788	562	560	560
Computer Literacy	3.76 (0.92)	3.57 (0.99)	3.75 (0.93)	3.76 (0.93)
Ease-of-Use	4.21 (0.90)	4.08 (0.92)	4.19 (0.91)	4.21 (0.89)
Distracted during Test (%)	31.38	47.33	37.14	36.43
Able to Follow Instructions (%)	87.36	72.00	81.97	87.48
Helpfulness of instructions:	4.38 (0.75)	4.05 (0.87)	4.29 (0.79)	4.37 (0.77)
Text				
Video	4.50 (0.85)	4.30 (0.93)	4.48 (0.87)	4.55 (0.75)

Note: Participants were asked to respond on a scale of 0 to 5 for Computer Literacy, Ease-of Use, and Helpfulness of instructions. Mean (SD) values are presented for these metrics. Ability to follow instructions and rates of distraction are presented as percentages.

Table 3
Summary of TAS test metrics by gender.

Metric	Female	Male
Number	1456	571
Average Computer Literacy	3.75 (0.91)	3.76 (0.96)
Test Length (%):	89.29	88.50
Too short		
About right	10.49	10.95
Too long	0.22	0.56
Ease-of-Use	4.20 (0.90)	4.18 (0.91)
Distracted during Test (%)	36.74	23.47
Able to Follow Instructions (%)	85.96	84.25
Helpfulness of instructions:	4.37 (0.76)	4.26 (0.79)
Text		
Video	4.51 (0.84)	4.39 (0.90)
Enjoy Procedure (%)	79.78	85.77

Note: Participants were asked to respond on a scale of 0 to 5 for Computer Literacy, Ease-of-Use, and Helpfulness of instructions. Mean (SD) values are presented for these metrics. Test duration, ability to follow instructions, rates of distraction and enjoyment scores are presented as percentages.

to be acceptable, with only a small percentage feeling it was too long (9.92 %) or too short (0.28 %).

3.5. TAS Test usability and acceptability by demographics

3.5.1. Age

There was only a weak relationship between age and ease-of-use. Participants reporting lower ease-of-use scores (2 or 3) were slightly older (median age = 67.3 years) than those who gave high ease-of-use scores ([4 or 5]; median age = 65.0 years; Mann-Whitney U test, $p < 0.001$).

Age was also only weakly correlated with perceived helpfulness of instructions; specifically, younger age was associated with higher ratings of text instruction helpfulness (Pearson's $r = -0.12$, $p < 0.001$) and combined text-video instruction helpfulness ($r = -0.15$, $p < 0.001$). However, interpretation of these relationships for participants over 70 years of age is limited due to the small sample size in the lower rating categories (scores 0, 1, or 2).

Additionally, we explored the relationships between age and various assessment dimensions. Age was found to have only a weak correlation with the ability to follow instructions ($r = -0.10$, $p < 0.001$) and ease-of-use ($r = -0.14$, $p < 0.001$) and no significant correlation was observed between age and level of distraction ($r = -0.01$, $p = 0.61$) or enjoyment of the test ($r = 0.00$, $p = 0.85$).

3.5.2. Gender

Table 3 summarizes TAS Test metrics by gender. Overall, most of the usability and acceptability scores were not associated with gender. The differences observed between male and female participants were not statistically significant for computer literacy (p-value = 0.989), ease of use ($r = 0.01$, $p = 0.69$), helpfulness of text instructions (p-value = 0.989), or of video instructions ($p = 0.992$). There was only a weak positive correlation between gender and distraction level ($r = 0.13$, $p < 0.001$), indicating that female participants were marginally more likely to become distracted during the test. There was only a very weak correlation between gender and enjoyment of the procedure ($r = -0.07$, $p < 0.001$), suggesting that female participants were marginally more likely to enjoy the testing process.

3.5.3. Level of education

Higher education levels were found to have only a very weak positive correlation with the ability to follow instructions ($r = 0.06$, $p = 0.01$), ease-of-use scores ($r = 0.06$, $p = 0.01$) and enjoyment of the procedure ($r = 0.08$, $p < 0.001$). No significant correlation was observed between education level and level of distraction ($r = -0.01$, $p = 0.80$).

3.5.4. Computer literacy

The mean computer literacy for the entire group was 3.74 (SD: 0.93) on a scale of 0 to 5: for male participants this was 3.76 (0.96), while for female participants it was 3.75 (0.91); see Table 4. There was no significant association between age, or gender, and computer literacy. Higher computer literacy had only very weak positive correlations with the ability to follow instructions ($r = 0.06$, $p = 0.01$), ease of use scores ($r = 0.18$, $p < 0.001$) and enjoyment of the procedure ($r = 0.05$, $p = 0.04$). There was a weak negative correlation between computer literacy and distraction level ($r = -0.07$, $p < 0.001$).

3.5.5. Cognitive function

There was no significant correlation between cognitive function and completion rates, or ease of-use scores for either SWM (-0.04; $p = 0.08$) or PAL (-0.04, $p = 0.11$).

3.5.6. Depression and anxiety

There was no correlation between depression and the ability to follow instructions ($r = 0.01$, $p = 0.71$), ease-of-use ($r = -0.02$, $p = 0.50$), distraction level ($r = -0.01$, $p = 0.51$), or enjoyment of the procedure ($r = -0.01$, $p = 0.74$). There was a weak negative correlation between anxiety levels and distraction level ($r = -0.07$, $p < 0.001$), indicating that individuals with higher anxiety levels were slightly more likely to be distracted during testing. Anxiety levels did not correlate with the ability to follow instructions ($r = 0.02$, $p = 0.35$), ease of use scores ($r = 0.01$, $p = 0.65$) or enjoyment of the procedure ($r = 0.04$, $p = 0.12$).

4. Discussion

We found that a novel unsupervised computerized test of motor, cognitive and speech function was feasible, usable and acceptable in a large community cohort of more than 2300 older adults in Australia. Importantly the cohort had a wide range of ages from 50 to 89, and wide range

Table 4
Summary of TAS test metrics across different levels of computer literacy.

Metric	Level 1	Level 2	Level 3	Level 4	Level 5
Participants	15	112	627	630	439
Females	7	67	444	414	294
Males	5	36	148	176	123
Ease-of-Use	3.87 (1.41)	3.80 (1.03)	4.13 (0.91)	4.26 (0.86)	4.45 (0.80)
Distracted during test (%)	46.67	37.50	34.13	30.79	27.56
Able to follow instructions (%)	66.67	88.29	87.72	87.92	90.89
Helpfulness of instructions:	4.13 (0.74)	4.10 (0.82)	4.31 (0.76)	4.40 (0.69)	4.57 (0.72)
Text					
Video	4.13 (1.41)	4.32 (1.05)	4.47 (0.80)	4.52 (0.79)	4.68 (0.75)
Enjoy procedure (%)	66.67	74.55	80.48	82.03	83.11

Note: Level 1–5 represents participants' self-rated computer literacy where 5 is the highest. Participants were asked to respond on a scale of 0 to 5 for Ease-of-Use and Helpfulness of instructions. Mean (SD) values are presented for these metrics. Ability to follow instructions, rates of distraction and enjoyment scores are presented as percentages. Participant numbers are presented as total counts.

of computer literacy, mood symptoms and levels of education; furthermore, we evaluated feedback from sessions completed in the home and in the research facility.

The key findings were that more than 80 % of participants could complete self-administered hand motor tasks, visuomotor tests and visual memory tests, and more than 90 % completed the speech tests. Gender was not associated with the feasibility, usability or acceptability of TAS Test, and there were only very weak associations (with $r < 0.1$) between age, education and computer literacy levels with completion rates (feasibility), ease-of-use scores (usability) and enjoyment (acceptability). The lack of any strong associations thus supports the utility of this testing paradigm as it will not be influenced by intrinsic population factors such as age and gender.

It is interesting that participants testing at home generally found TAS Test more user-friendly and less distracting compared to those in a research center environment. This discrepancy may stem from the familiar and personalized atmosphere at home, potentially contributing to higher satisfaction and better adherence to instructions, and further underpins the rationale for the development of at-home tests.

To the best of our knowledge, this is the first unsupervised online test of motor, cognitive and speech performance. Previous unsupervised cognitive tests, such as CANTAB [37] and Cogstate [39], have been developed, validated and generally well-accepted by a wide range of community users. For example, Ashford at al. [40] investigated the feedback from more than 11,000 users of Cogstate and they found that older age and lower education level were associated with lower usability ratings. Rhodius-Meester et al. [41] evaluated another self-administered, web-based cognitive test, cCOG, in 495 participants in both clinical and home environments; they found that participants with mild cognitive impairment (MCI) and dementia, as well as healthy controls, could complete the tests providing evidence that online cognitive tests are feasible across the dementia continuum. In terms of remote speech data collection, there are fewer online unsupervised tools than for cognitive tests, but one such tool is Talk2Me that is administered through smartphones or laptops; a study of 196 participants demonstrated the feasibility of Talk2Me but it is noteworthy that the majority of the participants were under 30 years old [42]. Ntracha et al. [43] were one of the first groups to investigate the feasibility of 'passively' collecting motor and speech data; 11 participants with MCI and 12 healthy controls had motor and speech data collected through a smartphone whilst they completed their normal daily activities at home. This study supported the feasibility of remotely collecting multimodal digital biomarker data from older adults.

For online video-based unsupervised hand motor tests, there are no other research groups that are using this approach specifically for assessing AD risk. Our own research studies (for example, Wang et al. and Li et al. [20,21]) have shown the effectiveness of computer vision and deep learning techniques in precisely measuring hand movement patterns, including in remote settings. Islam et al. [44] introduced an AI computerized video-based test to remotely assess hand motor performance in 250 people with Parkinson's disease and also found it to be feasible and acceptable. Using a standardized finger tapping task captured by a digital camera, participants were evaluated in an unsupervised setting at home and, like our findings, most people could complete the tests satisfactorily but lower educational levels were associated with lower usability scores.

The novel approach of TAS Test to combine hand movement data alongside cognitive and speech data leverages previous research demonstrating the sensitivity of these modalities in estimating subtle changes associated with early AD [12,16,17,28,46]. Multimodal analysis is a new AI technique that has recently been shown to improve detection of neurodegenerative disorders [23]; it combines multiple types of data, including imaging, genetic, and clinical information, which can enhance the accuracy and reliability of detecting neurodegenerative disorders. Thus, TAS Test holds significant promise as a community-level 'prescreening' tool to identify people at risk of AD who may benefit from more expensive, specialized tests such as blood biomarkers.

The key strengths of the study include the large community-based cohort of more than 2300 participants and the comprehensive evaluation of feasibility, usability and acceptability of TAS Test in participants' homes as well as a research facility. Additionally, we examined the influence of various demographic factors, such as age, gender, education level, mood and computer literacy, on the user experience. This thorough approach enables a deep understanding of TAS Test's suitability for diverse older adult populations as well as providing rich insights into how other similar computerized motor, cognitive and speech-based tests may fare in community cohorts. The limitations are also acknowledged; the sample was predominantly female and highly educated, with a narrow range of cognitive function that is predominantly in the normal range. The cohort is biased to those who are more technologically inclined and interested in health, as participants were recruited from the ISLAND project, which requires internet access and engagement with online education and health surveys. We did not collect information on ethnicity but most Tasmanian residents are White and of Northern European ancestry, and thus the cohort likely lacks ethnic diversity. These various sources of bias may potentially limit the generalizability of the findings. Another limitation of our study is that feedback was only collected from those who completed the full test battery. Future studies should include structured follow-up with non-completers to better understand barriers to completion and improve the user experience. While TAS Test can detect extended breaks between tasks through timestamp analysis, the current version has limited ability to detect brief interruptions during self-paced tasks. Future iterations should incorporate additional monitoring mechanisms such as task timeouts and automated detection of engagement lapses to improve data validity.

Future research should address these limitations by expanding the demographic diversity of the sample (including cohorts with a range cognitive impairment) and incorporating a more in-depth analysis

of user feedback, including qualitative analysis and more open- and participant-led questions; this will enrich our understanding of user experience and inform new iterations of TAS Test [45]. This is especially important for people with low computer literacy and English as a second language. Further work will explore the retest reliability of each test, both at home and in center-based settings.

In conclusion, we found that TAS Test is a feasible, usable and acceptable unsupervised online tool for collecting multi-modal data from older adults in the home and in the research facility. Importantly, the feasibility, usability and acceptability measures did not have strong associations with age, gender, education, cognition, mood and computer literacy. Further validation is required but TAS Test holds promise as a community-based low-cost tool to identify AD risk. Furthermore, there is strong potential for TAS Test to have far-reaching applications across a broad range of neurological disorders, such as Parkinson's disease and stroke, where unsupervised motor, cognitive and speech analysis are also required.

Declaration of competing interest

Jane Alty has received payment from Abbvie Ltd and Stada Ltd for giving medical lectures; and has received travel support from Michael J Fox Foundation, Novo Nordisk and Shake It Up to attend medical conferences.

Jane Alty is employed by the University of Tasmania and by the Tasmanian Health Service

Jane Alty holds stocks as the (unpaid) Medical Advisor for ClearSky Medical Diagnostics; no payments ever made on the stocks

Jane Alty receives royalties from CRC Publishing for co-authored medical textbooks

Quan Bai is employed by the University of Tasmania

Eddy Roccati is employed by the University of Tasmania

Kate Lawler is employed by La Trobe University

Renjie Li is employed by the University of Tasmania

James Vickers is employed by the University of Tasmania, a Board Member of the Dementia Australia Research Foundation and on the Advisory Committee for Goldster.

CRediT authorship contribution statement

Guan Huang: Writing – review & editing, Writing – original draft, Software, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Renjie Li:** Writing – review & editing, Supervision. **Eddy Roccati:** Writing – review & editing. **Katherine Lawler:** Writing – review & editing. **Aidan Bindoff:** Writing – review & editing, Validation, Supervision. **Anna King:** Writing – review & editing. **James Vickers:** Writing – review & editing. **Quan Bai:** Writing – review & editing. **Jane Alty:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Formal analysis, Conceptualization.

APPENDIX. Measurement Tool and Scoring Criteria for Hospital Anxiety and Depression Scale (HADS)

A.1. Measurement Tool

Hospital Anxiety and Depression Scale (HADS)

A.2. Anxiety

- Normal: Scores below the cut-off point.
- Borderline abnormal: Scores falling within the borderline range.
- Abnormal: Scores above the cut-off point.

A.2.1. Cut-off scores

- Normal: HADS-A score < 8
- Borderline abnormal: $8 \leq$ HADS-A score ≤ 10
- Abnormal: HADS-A score > 10

A.3. Depression

- Normal: Scores below the cut-off point.
- Borderline abnormal: Scores falling within the borderline range.
- Abnormal: Scores above the cut-off point.

A.3.1. Cut-off scores

- Normal: HADS-D score < 8
- Borderline abnormal: $8 \leq$ HADS-D score ≤ 10
- Abnormal: HADS-D score > 10

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