Paper:
http://dx.doi.org/10.3233/JAD-160545
Administering Cognitive Tests Through Touch Screen Tablet Devices: Potential Issues

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Accepted 28 June 2016

Abstract. Mobile technologies, such as tablet devices, open up new possibilities for health-related diagnosis, monitoring, and intervention for older adults and healthcare practitioners. Current evaluations of cognitive integrity typically occur within a clinical setting, such as memory clinics, using pen and paper or computer-based tests. In the present study, we investigate the challenges associated with transferring such tests to touch-based, mobile technology platforms from an older adult perspective. Problems may include individual variability in technical familiarity and acceptance; various factors influencing usability; acceptability; response characteristics and thus the validity of a given test. For the results of mobile technology-based tests of reaction time to be valid and related to disease status rather than extraneous variables, it is imperative the whole test process is investigated in order to determine potential effects before the test is fully developed. Researchers have emphasized the importance of including the ‘user’ in the evaluation of such devices; thus we performed a focus group-based qualitative assessment of the processes involved in the administration and performance of a tablet-based version of a typical reaction time test (a multi-item localization task), to younger and older adults. We report that the test was regarded positively, indicating that using a tablet for the delivery of such tests is feasible, it is important to consider factors surrounding user expectations, performance feedback, and physical response requirements in order to inform further research into such applications.

Keywords: Aging, attention, cognition, focus groups, qualitative research, tablet computers

INTRODUCTION

The past five years have seen a rapid growth in the number of people over the age of 65 using mobile devices. Almost one in five older adults in the United States possess a smart phone with increased usage driven by factors such as the advanced capabilities of smart devices, the value placed on the ability to communicate with relatives, and the perceived usability of touch screen technology [1, 2]. The trend opens new avenues for adjuncts to health-related diagnosis, monitoring, and intervention and thus the delivery of healthcare to a population that typically find it hard to access such services. This is of particular relevance for older adults who are increasingly at risk of developing dementia and associated disorders, and an often-corresponding reduction in both mobility and the ability to access healthcare services. As a result of increased engagement with digital technology devices such as tablets and smart phones, mass healthcare monitoring in older adulthood is a real possibility. Furthermore, healthcare solutions

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scale up for a large number of users and demand.

Telecare technology (mHealth) has been entering different healthcare challenges to living with chronic conditions such as Alzheimer’s disease, vascular dementia [13–16]. As RT speed and variability appear to be behavioral indicators of the integrity (at least in part) of white and grey matter [17] in older adulthood and neurodegenerative dementia processes such as Alzheimer’s disease, such measures may be of use clinically.

Arguably, RT and IIVRT testing appear particularly suited to delivery or presentation via a touch screen tablet as they tend to be cheaper and simpler to use than laptops or desktop computers and can have multiple advantages over computers for testing information processing in older adults [9, 18, 19]. However, it is also increasingly clear that factors unrelated to brain structure and function and a disease process can influence RT and IIVRT and that it is vital to determine, investigate, and ameliorate such effects with respect to the touch screen tablet platform, in order to ensure test validity.

Evidence already reveals that there are a number of challenges to be aware of when digital technologies are used by older adults including physical issues such as decline in manual dexterity and eyesight and decreasing cognitive capabilities, frustration, the need for specific training, age, gender, dry finger skin, and age-related cognitive motor skills [2, 18–22], all factors likely to affect the performance of RT and IIVRT tests using a touch screen platform and thus their clinical validity, usefulness, and robustness. Furthermore, RT research has revealed many participant and methodology-related factors capable of significantly affecting RT study outcome including: the test item, the environment, response requirements,
Fig. 1. A screen shot of the iPad MILO task used in the current study. Participants can perform sequences of actions [29, 30] to other well-established paper-and-pencil tasks (e.g., The Trail Making Task [31]) and computer-based cancellation tests [32] in requiring a target to be identified in a specific order. A typical trial from the tablet implementation that was used in the current study is presented. The participant would be to touch all items in sequence, from one to eight. The general advantages of computer-based presentation as compared to paper-and-pencil tasks include the recording of RTs for each item, rather than simply overall completion time (e.g., [32]) and the ability to easily explore spatial patterns of search organization (e.g., [34]). In addition to these, the MILO task makes it possible to easily manipulate the sequence type (e.g., letters, digits, or both) and sequence behavior (e.g., items vanishing or remaining, sequence position remaining fixed or shuffling between responses), to explore the temporal context of visual search [29]. Such a task therefore represents the type that might be considered for use in a clinical situation, providing information about RT speed and variability, and attention processing and other aspects of higher level, cognitive processing.

MATERIALS AND METHODS

For the purpose of the current study, we used a fixed sequence of the digits one to eight, and configured the display so that items vanished when touched. Although this MILO configuration was not initially designed specifically for use with older adults, we chose the task specifically because the display layout and physical response demands were appropriate for use with this population [35–37]. For example, there are a number of challenges to be aware of when digital technologies are used by older adults including physical issues such as decline in manual dexterity and eyesight and decreasing cognitive capabilities, both potentially hindering interaction with mobile platforms, which are not adapted to their needs [18, 19, 22]. In the MILO task, the target object size and spacing were well within these suggested limits and responses could be self-paced. More specifically, when the iPad was placed on a table 50 cm in front of participants, each 1.9 cm item subtended approximately 2° visual angle, with gaps between items varying between 0.8° and 8° visual angle. To successfully complete a trial, participants were required to touch each object following the numeric sequence one to eight as quickly as possible, but there were no specific time limits, so participants could calibrate their responses taking into account any motor limitations.

When an item was touched, it vanished from the screen, so that the set size, and search difficulty was reduced with each response. Touching an item out of sequence (i.e., a mistake) resulted in the termination of the trial and visual feedback in the form of a schematic sad face. There was a two second intertrial interval and no feedback on speed or accuracy was provided for correct trials. Each participant completed 10 training and up to 10 experimental trials and at the start of each trial the position of all target items was randomized within the constraints of a virtual grid that was programmed to ensure items did not overlap. As our goal was to explore factors related to presenting a RT task using a touch screen tablet format per se, we did not record actual RT performance as participants were allowed to comment upon any aspect of the task while they were doing it. Instead, as detailed below, we used a focus-group design to make a qualitative assessment of individuals’ experiences and device usability.

In an approach that is interdisciplinary and draws from Human Computer Interaction (HCI) and User Experience (UX) research traditions, a focus group approach was adopted in order to determine from the individuals themselves potential issues relating to the use of mobile technology for cognitive testing that may influence the RT results. To provide information of relevance to real life test scenarios, as it is common in MILO and similar computer-based tests of attention and cognition to provide on-screen feedback using a visual or auditory warning indicative of incorrect response, we also investigated the potential use of such feedback.
real-time feedback upon task acceptability. Furthermore, the researcher administering the test typically sits close to the individual taking the test; anecdotally this has been off-putting to the person taking the test, but it may also be reassuring. Therefore, we also examined this factor in our research and found no effect on task acceptability and performance.

Jenkins et al. [28], recruited eleven younger adults (18–30 years) and twelve older adults (65+ years) for a one and a half hour focus group. The younger adults were recruited via University block-notes, and word of mouth. The older adults were recruited via the Older People and Ageing Research and Development Network (OPAN) and Local 50+ Networks. Poor general health, sensory limitations and participation in similar research studies formed exclusion criteria. Two members of the research team were present, one leading and the other observing and taking notes. A semi-structured schedule was followed. The methodology is discussed in full in Jenkins et al. [28], but to reiterate; there are of course limitations and participation in similar research studies formed exclusion criteria. Two members of the research team were present, one leading and the other observing and taking notes. A semi-structured schedule was followed. The two members of the research team read and re-read the transcripts making initial comments and codes. The process was repeated twice more until individual codes were identified. Subsequently these were grouped into three major themes that emerged across both younger and older participant groups, namely ‘views of test experience’, ‘testing situation and materials’, and ‘test performance’.

**RESULTS**

A number of themes and sub-themes have been identified highlighting categories rather than prevalence. These are presented in Table 1 below.

<table>
<thead>
<tr>
<th>Focus group section</th>
<th>Questions and prompts</th>
</tr>
</thead>
<tbody>
<tr>
<td>iPad test feedback</td>
<td>- Has anyone used an iPad/similar device before?</td>
</tr>
<tr>
<td></td>
<td>- How would you describe your experiences of using the test?</td>
</tr>
<tr>
<td></td>
<td>- Prompt - was it enjoyable or not?</td>
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<td></td>
<td>- How well did you think you have done?</td>
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<td></td>
<td>- What parts of the tests did you find challenging?</td>
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<tr>
<td></td>
<td>- Prompt - was it too fast? Hard to pay attention to, etc.?</td>
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<tr>
<td></td>
<td>- Was the iPad easy to use?</td>
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<tr>
<td></td>
<td>- Prompt - were you able to see the visual feedback?</td>
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<td></td>
<td>- What parts of the tests did you find challenging?</td>
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<td>- Prompt - was it enjoyable or not?</td>
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<tr>
<td></td>
<td>- Was the iPad easy to use?</td>
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</tbody>
</table>

Table 1: Focus group schedule (iPad test experience)
Fig. 2. Views of test experience.

The sub-theme ‘absorbing’ which represents some of the older participants said they were absorbed into the iPad test experience. For instance:

“[W]: I found it quite absorbing myself because you had to concentrate on what was in front of you to pin point what the next number was. I have to say it occupied all my thoughts I was just trying to do it as quickly as I could, and as accurately as I could. I was totally absorbed by those 1–8 numbers. Which is strange for me because my mind does tend to wander and it didn’t wander on that occasion.”

The second sub-theme reflects the older participants’ competing views that the test was a ‘challenge’, and the third sub-theme that it was ‘easy’. For instance:

Challenge: “[J]: I found it absolutely entertaining. I found it quite a challenge [mumbling]. I was sort of trying to do it quite quickly, I failed a couple of times but I think that was these [pointing out his fingers].”

Easy: “[RA]: I thought it was easier than I thought it would be. I thought ‘I have never used an iPad before!’ And sometimes when I go onto the computer I press something and it goes off, I have done that a few times actually. The iPad I made a few mistakes”.

The sub-theme ‘positive experience’ was a shared view of both the older and younger groups. For instance:

Positive experience (older): “[P]: it was quite enjoyable. [W]: and I think the more you did it the more you wanted to do it somehow”.

Positive experience (younger): “[R]: fab, thank you. Did you enjoy doing the test? [A]: it makes me want one [iPad]. [P]: it was interesting but I wouldn’t use the word ‘enjoy’ [laughter] I was just counting dots but it was a little more engaging that some can be. [S]: it made me wonder if they were dots or pool balls [laughter] I think it was nice that it changed on each trial. Like in a paper pencil version of a trail making there is only one set way of doing it and I like having the variation that it is new every time you do it, maybe it is more accurate that way”.

The sub-theme ‘boring and distractible’ is also a shared view in opposition to the test being a positive experience. For instance:

Boring and distractible (older): “[R]: so how did you find the test? [G]: a bit boring I found it, sorry. Repetitively boring there was obviously a sequence for that. I said that to [researcher] I said ‘is this um could you memorise these if you had a good memory and numerative memory?’ The problem is going too fast and then thinking something more interesting may come up next time. It was the same numbers just in a different location. Yeah I found it boring towards the end. [R]: yes and that is perfectly fine, I want you to be as honest as you can. Thank you [G]”.

Boring and distractible (younger): “[R]: ok, so would you say then something like that could be used on a regular basis or would you say no? [L]: I think it was boring”.

The final sub-theme is unique to the younger group and represents the view that the test was like a ‘game’. For instance:

“[B]: it was like many games that you can get on the iPad already, like I have a few already that are similar. [R]: are there any that you think are similar to it? [S]: I wouldn’t know. [A]: not sure. [P]: when she was initially explaining it to me it did kind of remind me almost of like a word search type thing because you are obviously looking for like a 1 and then linking it. [B]: I have quite a few games where you have to link patterns between things and there is ummm well I have about 5 on here and there are millions available as well like [famous game]. [R]: yeah it is a similar thing”.

The diagram shows the views of test experience.
isn't it. [S]: see I was thinking well what the purpose of the game is, what it is going to be used as. For example, if it is something to do with cognitive training then I wondered what well if it would be of any use to have like a kind of positive feedback mechanism put in because I made a mistake and there was a little sad face and that was feedback too but you know to get people to play it maybe more regularly maybe it would have like increasing difficulty and a score. That would make them go back to it. I don't know if I would play it regularly just for the sake of doing it as it is now because it is just like tapping the numbers and I want to know that I am doing good. [A]: yeah like in games you want to improve and beat your score. [S]: yeah like progression or how well I am doing. [B]: or different levels, like the next level could have 10 numbers”.

Testing situation and materials

This second theme has three sub-themes developed from the findings of both the older and younger groups. The first sub-theme reflects the views regarding the experience they had of using the iPad. For instance:

Device experience (older): “[R]: yes but she wasn’t giving scores, what’s more important is the feedback from the tests. Did you find it easy to use? [A]: yeah. [G]: well I did very well but it was fine. [J]: I was a bit more accurate. And these glasses [glasses], but it was difficult to keep them back up. [R]: yeah ok so...”

Device experience (younger): “[R]: ok, thank you. How about the positioning of the iPad? [L]: fine. [P]: I moved it. [R]: where did you move it to? [P]: I just moved it closer. The angle was a bit well I didn’t move the angle. For me it would have been better flat but maybe because it was quite far into the table. [RB]: it would have been helpful to have one of those holders, what are they called? [P]: like a copy holder? [RB]: yeah, just to have it in front of you. I wonder what that would have helped.”

The second sub-theme is the shared collection of views regarding the ‘test environment’ of both age groups. For instance:

Test environment (older group): “[N]: I was very conscious that [researcher] was watching me. [J]: yes and me. [N]: so I wasn’t quite relaxed doing it from that point of view. I was still conscious that someone is watching me doing this and you think ‘what are they thinking? Are they taking a note on how I am approaching this?’”

Test environment (younger group): “[R]: ok, thank you. How about the positioning of the iPad? [L]: fine. [P]: I moved it. [R]: where did you move it to? [P]: I just moved it closer. The angle was a bit well I didn’t move the angle. For me it would have been better flat but maybe because it was quite far into the table. [RB]: it would have been helpful to have one of those holders, what are they called? [P]: like a copy holder? [RB]: yeah, just to have it in front of you. I wonder what that would have helped.”

Fig. 3. Testing situation and materials.
would be different. So I don’t know, again in terms of the instructions of the set way of doing the task maybe there has to be a certain distance from the screen or uh I don’t know, something that would make sure it is standardised for everyone”.

Test performance

This theme has six sub-themes, four of which are shared between the two age groups, and one unique to each (Fig. 4). The theme relates to how the participants felt they performed at the iPad test. The first sub-theme ‘accuracy’ is based only on the older participants. For instance:

“[R]: so what did you think? Was it due to more accuracy or speed? [N]: a combination of both I think. [P]: yeah it is no good going fast if you’re going to get it all wrong is there. [J]: I was disappointed with the number of mistakes I did make, obviously trying to go too fast. [P]: I made one but I think it was because I didn’t press hard enough on the screen. The face came up [showing sad face]”.

The second sub-theme is the ‘use of hands’ whilst using the iPad. For instance:

Use of hands (older group): “[A]: the only problem I had with the touch screen is my nails. I have this problem at home, and that’s why I use a [brand name] pen because I find you have to develop a certain technique of touching. You can’t just go like that [action] because your nail would touch it and that doesn’t work so you have to slide off rather than…and I found that at home. But as I
The third sub-theme ‘speed’ is also shared by the older and younger groups. It reflects the speed participants thought they were supposed to go, or did go when using the iPad. For instance:

Speed (older): “[G]: we know ultimately what the tests are about and that’s cognitive impairment. [A]: or is it speed. [G]: I don’t think speed matters; it’s a balance between speed and accuracy. [M]: I think accuracy. [R]: there are lots of factors, there’s speed and accuracy. [R]: so how do you feel (J)? [J]: I would say about 85%, I think it was ok.”

Speed (younger): “[R]: so did you find the test enjoyable? [L]: in the beginning. [C]: yeah with my competitive edge to it. [L]: yeah I was a bit wish we was being timed and we knew we done. I get really competitive, I need to do this the quickest out of everybody, I was going for it. [C]: it’s not all about rewards because a reward is obviously a motivator to do well but for me thinking that someone could see a bad kind of response, that would make me want to do even better because I would like ‘I don’t want to be the slow one’ [P]: I work better with positive reinforcement so something to say ‘that you’re doing well’ because if you show well you performed in the worst quartile well I would be like oh I cannot be bothered now, but that’s just me I don’t work very well with punishment. [L]: I am the same. [RB]: yeah like it kind of deflates you a little bit so maybe performance goes down with that as well maybe. [L]: yeah so maybe that unhappy face could spur someone on to do better and faster but then other people will see that unhappy face and think ‘oh no!’. [P]: it put me off completely. [RB]: same [laughter]. I knew [researcher] was sat next to me and I didn’t want her to see the faces. [R]: do you think it would have made a difference if [researcher] was not in the room? [RB]: yeah, I didn’t want her to see it so I kept well at that angle she couldn’t have. [B]: it does show that the unhappy face does mean more”.

The sub-theme ‘tactic’ refers to the tactics both the older and younger groups had when completing the iPad test. For instance:

Tactic (older): “[JC]: I used the one finger all the time, I think I intuitively was picking out the first four numbers and then the other four. Also, I am very competitive, I was trying to go faster and faster so not much focus on being accurate so I had two errors.”

Tactic (younger): “[C]: yeah and also like how I went about it, like at the start I was just like looking 1, 2, 3, 4, as opposed to once I had an unhappy face it changed how I did it, like I was looking at groups so I would find 1, 2, then 3 and 4, then 5 and 6, and I found that I was quicker because it would take me an extra second to look but I tap quicker then because I already knew where the other one was. So I changed how I attended to it. [L]: changed your strategy. [C]: yeah”.

The final shared sub-theme is ‘performance feedback’ which relates to how much feedback they would ideally like to have had from performing the iPad test. For instance:

Performance feedback (older): “[N]: I have to say I would love to know how well I did. I would like to have some feedback on it. I think most of us who have done a test would like that. And what I assume is looking at how many mistakes someone makes is information I would like to have in feedback you know”.

Performance feedback (younger): “[R]: fab ok, how did you find it? [B]: same here yeah and then I got an unhappy face then all of a sudden I was like "wow slow down". [RB]: I didn’t get an unhappy face. [B]: I got two. [L]: I got two. [C]: I got two. [L]: but I think my finger accidently went too far next to the other ball, basically I shouldn’t have had the second unhappy face. [P]: do you want to appeal the judgement? [Laughter]. [L]: 1176 A. Jenkins et al. / Administering Cognitive Tests: Tablet Devices
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I do yes [laughter]. [P]: see you have got no
I have to hit the keys with my podgy
[C]: yeah it was like 6 and 8
liked similar, that was the two that I
rong. I went for an 8 instead of a 6
look so similar, but I knew straight
it wrong”.

The phrase ‘search strategy’ is unique to
It reflects the strategies employed
younger participants to perform the
ance:
whether it depends on how you attend to
look at the holistic picture and
ally sit back and look at the whole
at point you’re more susceptible to
because I could just sit there with
then if they were split between left
and it easier to go from one side of
the other using two hands rather
are grouped around one area”.

The main aim of this study was to pro-
og-based qualitative evaluation of
ctic test on a mobile device and
ceptability with both younger and
icularly related to the participant’s
tel technology. The potential influ-
back and researcher presence
ance was also examined.

numbers just in a different location. Yeah I found it
boring towards the end. [R]: yes and that is perfectly
fine, I want you to be as honest as you can. Thank you
[G]”. The younger participants also expressed the test
experience as positive, for instance, “[R]: fab, thank
you. Did you enjoy doing the test? [A]: it makes me
want one [iPad]. [P]: it was interesting but I wouldn’t
use the word ‘enjoy’ [laughter] I was just counting
dots but it was a little more engaging that some can
be. However, others also deemed it to be ‘boring and
distractible’, thus “[R]: ok, so would you say then
something like that could be used on a regular basis
or would you say no? [L]: I think it was boring”.

Feedback

In the MILO test, performance feedback was given
in the form of an unhappy face icon when a mistake
was made. However, we can see from the comments
made in this study that in real life, rather than pro-
viding a potential learning opportunity, via feedback,
such an icon can have a demoralizing effect, with
evidence that an individual experiences embarrass-
ment if an observer can see the unhappy faces, i.e.,
their poor performance. These factors may detrimen-
tally affect test results and render the individual less
likely to want to do the task again. Related to this was
the finding that people could feel very self-conscious
when being watched; again the presence or not of an
observer may affect an individual’s test performance.
A number of participants were embarrassed at the
thought that the researcher present could see if they
had an unhappy face pop up. Although this might not
be of importance if the tests are self-administered,
it is a pertinent consideration when administered by
another individual.
feedback per se and how it is pre-
not made clear. For instance, the level of education
about the systems purpose, i.e., is it the speed or the
accuracy of their performance which is most impor-
tant? There was much disparity regarding what the
participants thought was most important despite clear
instructions given prior to the start of the test. Their
lack of clarity could have been due to their preoccu-
pation with the testing situation. If so, then it should
be made a priority that they fully engage with the
instruction process prior to the start of the test. The
inclusion of a practice trial could be implemented in
the future.

These issues seem to suggest that participants
might have treated the test more like it was a video
game as opposed to a cognitive test with an approach
that involves strategizing to maximize the score they
receive and possibly an increased sense of motiva-
tion or competitiveness with other players to get a
“high score”. Researchers have not examined the atti-
dudes and motivations of people who engage with
cognitive testing, however, the motivations for video
game play are quite well understood. Engagement
with video games can be intrinsically motivating with
reward derived from simple actions and immersion
in game [39] or motivation can be derived from a
sense of challenge or competition in the game and
the accomplishment that come with it [40]. In con-
ventional video games, these motivators can drive
people to practice/play more and become extremely
skilled with the games, improving their scores and
their visuospatial awareness [41]. The questions this
raises for the digital tests are first, whether the test
motivates practice in the same way a game does,
and second, whether this practice invalidates the test.
For example, if one becomes too practiced, then test-
performance ceiling effects can be induced.

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In the room could also interfere the ability to see the stimuli. Again, the tilting stand could assist in reducing the lighting in the room could also interfere the ability to see the stimuli. Again, the tilting stand could assist in reducing the lighting. But also the researcher should take into account when selecting an appropriate environment.

Having long finger nails physically hindered users and affected their responses as they were not able to accurately touch to the screen. Participants were asked to touch the stimuli upon the screen. The participants suggested the use of a pen/pointer instead of relying on the skin conductance of their fingers. This would also alleviate the need for too much emphasis being put on the physical ability to respond appropriately as some participants had large fingers, and having arthritis in their wrists, hands, or fingers (see above). Some of the participants requested the use of a pen/pointer instead of touching the screen with their fingers. This indicates the importance of considering when developing such a test.

Participants suggested the use of a pen/pointer instead of relying on the skin conductance of their fingers. This would also alleviate the need for too much emphasis being put on the physical ability to respond appropriately as some participants had large fingers, and having arthritis in their wrists, hands, or fingers (see above). Some of the participants requested the use of a pen/pointer instead of relying on the skin conductance of their fingers. This indicates the importance of considering when developing such a test.

Efforts at target eleven, all targets located in a random order around the table. The authors used Fitts' Law to compare the measurements on different Android tablet sizes. Their initial findings show that factors such as age and gender as well as dry-finger displays are not an optimal choice. However, they argue touch-displays are easier and more intuitive to use for older adults. For example, Culén and Bratteteig [44] argue touch-displays are easier and more intuitive to use for older adults. They may become a better match. There is no robust evidence in the HCI literature supporting this commonly believed argument. [43], there is no robust evidence in the HCI literature supporting this commonly believed argument.

Burkhard and Koch [45] asked 30 older adults to perform eleven single taps (eleven targets) in a sequential key-pressing was not a straightforward task, (2) they tended to press too slowly or pressing the wrong target, (3) slow timing and the rhythm of key-pressing: (1) Doing one longer period of time than the other, (3) slow and movements.

It has been argued that touch-displays are intuitive to use for older adults. However, robust evidence in the HCI literature is commonly believed argument. That elderly people with dry or wrinkled fingertips had a significantly higher touch recognition error rate on some tablets. This could also be related with the layer types of the resistive touch-screen technology. Harada et al.’s [46] study also support dry-finger and users’ frustrations with unresponsive taps.

CONCLUSION

Arguably iPad-based tests may be an ideal base for home testing, with subsequent increased compliance in clinical trials, longitudinal clinical and research follow up, and the ability to signal deterioration and thus to facilitate intervention, but many factors need to be considered in their development if such tests are to reliable, valid, and objective. The participants in this study highlighted several issues pertinent to the development of tablet or mobile-based tests typical of those used in the assessment of cognitive function in older adults, which can then be used to inform more specific development for testing in individuals with cognitive impairment and dementia. In order to inform those considering developing tasks of RT and other aspects of cognitive function on touch screen based tablets, we summarize the information gained from our focus groups in the following section in a series of bullet points. It is clear from this information that many factors, which may not be currently taken into account when designing such tasks for use on touch screen tablets, but which, without being addressed could significantly influence task performance and thus adversely affect the clinical validity of such a test.

- Without highly specific instructions, response strategy to test components and stimuli can vary between individuals, despite clear instructions given.
as the use of visual aids is of great importance when developing such tests, see also [42]. A suggestion from some of the participants was that the tablet should be placed in a tilted stand, and indeed spontaneous tried to hold it in this position so they could see the stimuli. However, although this position may ameliorate some physical difficulties, it is possible that it may affect performance in other ways as yet investigated and thus once again consistency of positioning would be highly important. The positioning of the tablet in relation to lighting in the room can also interfere with the ability to see the stimuli, thus lighting becomes an important consideration when selecting the testing environment.

There are of course limitations with our focus group study. For example, individuals living with dementia or cognitive impairment were not included, and it is possible that test administration, reaction to it, and performance varies with the integrity of cognitive function. Future studies should include a wider range of tests and their validation with other forms of computerized testing, groups representative of a wider range of age-related changes such those found in relation to vision (such as cataracts, wearing glasses, color blindness), hearing, mobility and dexterity, memory function (what happens if individuals forget the instructions?), and levels of motivation and response confidence (e.g., examining the potential for guessing the response). Other pertinent factors for developers to consider in the future.
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Acknowledgments


