Design of a Mobile-Based Neurological Assessment Tool for Aging Populations

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Abstract. Mobile devices are becoming more pervasive in the monitoring of individuals' health as device functionalities increase as does overall device prevalence in daily life. Therefore, it is necessary that these devices and their interactions are usable by individuals with diverse abilities and conditions. This paper assesses the usability of a neurocognitive assessment application by individuals with Parkinson's Disease (PD) and proposes a design that focuses on the user interface, specifically on testing instructions, layouts, and subsequent user interactions. Further, we investigate potential benefits of cognitive interference (e.g., the addition of outside stimuli that intrude on task-related activity) on a user's task performance. Understanding the population's usability requirements and their performance on configured tasks allows for the formation of usable and objective neurocognitive assessments.

Keywords: Neurocognitive tests · Parkinson's Disease · Mobile app

1 Introduction

Mobile devices are becoming more pervasive in the monitoring of individuals' health as device functionalities increase as does their overall prevalence in daily life [1]. As individuals age, the challenges associated with using these mobile health apps increase particularly due to cognitive and motor issues [2,3]. App designs for usability and monitoring need to take these factors into account considering the prevalence of cognitive decline and neurodegenerative diseases in the aging population. Traditionally, neurological conditions have been assessed in clinical settings using various accepted pen-and-paper style assessments [4]; however, technology and its capabilities allow for the collection of far more information and objective metrics than we ever could achieve using pen-and-paper style tests [5]. Cognitive screening instruments such as the Montreal Cognitive Assessment (MoCA) [6], Mini Mental State Examination (MMSE) [7], and the Menu Task Assessment (MT) [8] are usually initially given whenever a progressive or acquired neurological condition (e.g., Parkinson's Disease, dementia, stroke, etc.) is suspected. These assessment instruments consist of functional tasks such as, motor (e.g., fine and gross motor), speech, memory, and executive

J. Ye et al. (Eds.): MobiHealth 2020, LNICST 362, pp. 166–185, 2021.
https://doi.org/10.1007/978-3-030-70569-5_11

function all or some of which may be difficult for individuals with neurodegenerative conditions like Parkinson's Disease (PD) [9–11]. Subsequently, the transition of cognitive assessments from paper versions to mobile devices calls for the configuration of tasks to be clear and usable by individuals with diverse abilities and conditions as to not impair their performance or assessment results. Therefore, a focus should be placed on mobile user interface design, task design, and overall usability to accommodate these potential user impairments while maintaining the requirements of the functional test [12].

The objective of this paper is to address the issues of usability and efficient assessment design to accommodate the aging population both with mild cognitive impairment and with recognized neurodegenerative disabilities. This paper proposes designs of the user interface, specifically testing instructions, layouts, and subsequent user interactions. In addition, functional task designs are explored to understand the potential benefits of cognitive interference (e.g., the addition of outside stimuli that intrude on task-related activity) on task performance. This paper focuses on individuals with Parkinson's Disease since they demonstrate impaired functionality of both motor and cognitive tasks [13].

Individuals diagnosed with PD were compared to age matched control individuals across mobile neurocognitive assessments for both usability and task performance. Changes in the user interface design were intended to accommodate known disease symptoms (e.g., deficits in motor function, memory, executive function, and/or speech). Usability of these neurocognitive assessments were enhanced by modifying the overall test layout, screen interactions (e.g., button sizing and location), and instructions (e.g., multiple versions for complete understanding of the required task) for all types of functional tests (e.g., motor, memory, and executive function). In addition different methods of cognitive interference on functional areas of cognition (e.g., motor, memory, speech, and executive function) were explored for the understanding of a user's task performance and subsequent functional task designs. Cognitive interference is the addition of outside information that intrudes on task-related activity and serve to reduce the quality and level of performance [14]. Cognitive interference occurs when the processing of a specific stimulus feature impedes the simultaneous processing of a second stimulus attribute [15]. This interference can be derived from many sources, however, maintaining testing design, layout, and desired functionality between mobile assessment versions allows for the understanding of cognitive interference in functional task versions.

2 Related Work

2.1 Testing Layout

Functional assessments should aim to minimize any additional outside cognitive load for the user (e.g., the used amount of working memory resources). This allows the user to focus only on the required tasks (e.g., motor, speech, memory, executive function, or designed dual-task assessments). This would include the formation of simple test views (e.g., splitting information into sub-views to minimize amounts of material on the device screen) and instructional design (e.g., having only relevant information included) [2]. Further, the test layout should minimize errors caused by user screen interactions through the placement of navigation components in positions that are accessible but not error prone [16].

2.2 Screen Interactions

Touch technology on mobile devices must accommodate users with motor impairments (e.g., minimizing unwarranted button presses while a user completes a required functional task like tracing a shape on the device screen). Button location and sizing are both important factors necessary for user interface design for aging individuals and individuals with motor impairments [3,17]. Screen interactions for right-handed users, typically result in significantly more time and effort to reach the upper left and lower right corners of the device. The opposite occurs for left handed individuals (e.g., resulting in significantly more time and effort to reach the upper right and lower left corners of the device). However, many current touchscreen interfaces have essential system functionality located in these areas; especially the top and bottom corners of the device screen [16]. Further, device users tend to prefer and perceive bottom bar navigation menus better than other types (e.g., the hamburger menu), and it is seen to be more efficient [18].

2.3 Testing Instruction

As testing becomes readily available on mobile devices, it is important to maintain comprehensive instructions similar to clinical settings (e.g., having a trained clinician explain the testing protocol to the user and/or answer any clarification questions). User interpretations of instructions based on impairment, and/or language barriers may lead to possible data quality and consistency issues [4,19]. Similarly, multiple forms of instruction (e.g., short explicit texts and clear visual demonstrations of actions the user is required to perform) aid the users in understanding the required actions of the test [4,20]. The method in which these different users understand the functional assessments may change based on the assessment focus (e.g., motor function, speech, memory, executive function, or dual-task assessments) or their preferred learning style (e.g., visual or auditory).

2.4 Cognitive Interference

Since individuals with neurodegenerative conditions (e.g., Parkinson's Disease) demonstrate impaired functionality of both motor and cognitive tasks [13], the assessment of these functional areas of neurocognition should occur in multiple approaches. These can be assessed using both single and dual-task testing approaches [21,22], both of which can examine cognitive interference effects.

Table 1. Functional tasks

Functional task	Function(s)	Reference
Card matching task	Memory	[25]
Reaction time task	Motor function	[26]
Word sequence task	Speech	[27]
Trail making task	Executive function/motor function	[23]
Apraxia tasks	Motor function/speech	[28]

Single Task Interference. The purpose of single functional tasks is to focus on one primary area of neurocognition (e.g., motor function, memory, or executive function). A set of single modal tasks are seen in Table 1. Card matching, reaction time, and word sequence tests are all seen as single function tests as they monitor one main area of cognition. In the trail making task, testing configurations allow for the focus on one primary area of neurocognition (e.g., executive function), even if an individual's motor function carries out the executive function task. Structural variations (e.g., different visual cues or changing of depicted features) can lead to the implementation of cognitive interference(s) [23,24]. Understanding the extent of how these possible interference configurations affect individuals both in PD and control groups is of interest and will be explored in this work.

Dual-Task Interference. Dual-tasks involve two functional areas of neurocognition equally (e.g., walking and talking) at the same time [22]. Dual-tasks have inherent interference as the processing and/or production of each of the functional cognitive aspects (e.g., motor and speech) causes an intrusion in the other. When this method is employed for individuals with neurological conditions, it is to understand the prioritization strategies of the required activities compared to control groups [13]. Table 1 provides a depiction of dual functional tasks. Understanding different configurations of dual functional tasks for the areas of motor and speech across PD and control groups will be explored in this work.

3 Application Design

3.1 Test Layouts

As neurocognitive assessment instruments consist of multiple tasks, an assessment instrument should take into consideration the minimization of any additional outside cognitive load to the user (e.g., the used amount of working memory resources needed) during each task [2]. This can be accomplished by minimizing the number of screen interactions by the user (e.g., minimizing unwarranted button presses across assessments) [16] and maintaining all test instructions and interactions on the task application screens [4,20]. Each test layout design (Figs. 1 and 2) therefore was formatted to provide all necessary testing information without the need for navigating to other pages or requiring additional button presses by the user.

3.2 Test Instruction

Testing instructions were given to the user verbally (e.g., by a test proctor or clinician) [19] and via the tablet (e.g., short explicit texts and clear visual demonstrations of actions the user is required to perform) [4]. Figure 1 shows the instructional and interactive views of a fine motor functional tracing test. The instructional view provides the user all testing instructions and a partial demonstration (e.g., the image of an index finger with a trailing blue line). Once the user interacts with the tablet (e.g., "tap to begin"), the interactive view removes the demonstration image while the user is still shown the rest of the instructions to complete the test. Figure 2 shows samples of interactive views for gross motor function, memory, and executive function based tasks.

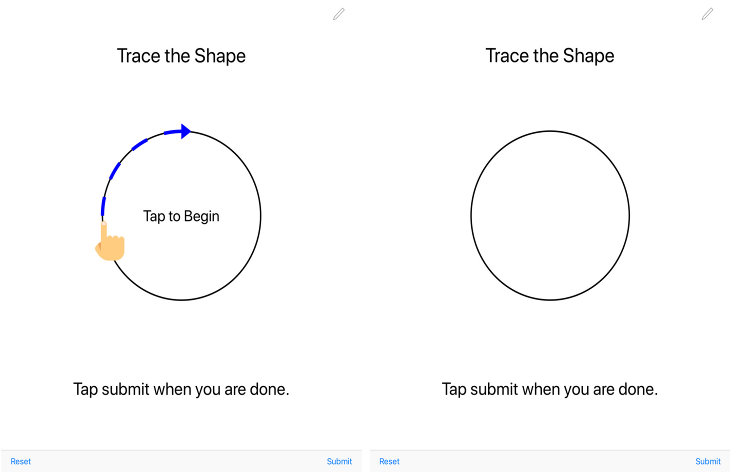

Fig. 1. Sample instructional and interactive views of a fine motor functional tracing task. (Color figure online)

3.3 Test Interactions

The partial demonstration shown in Fig. 1 depicts how the user is intended to interact with the fine motor tracing test (e.g., using their index finger to trace the shape, in a clockwise motion starting from the left). The user is to tap on the screen to enable the interactive view, and then trace the depicted shape based on the given instructions. A gross motor task would include tapping on the screen to enable the interactive view so they may manipulate the mobile device to "air"-trace a prompted shape (e.g., asking the user to hold the device directly in front of them with both hands, arms outstretched and move the device to emulate a shape). Examples of a memory test would include tapping on cards in pairs until all cards have been matched. In the trail making test the user is intended to draw a line using their index finger to connect the dots in increasing

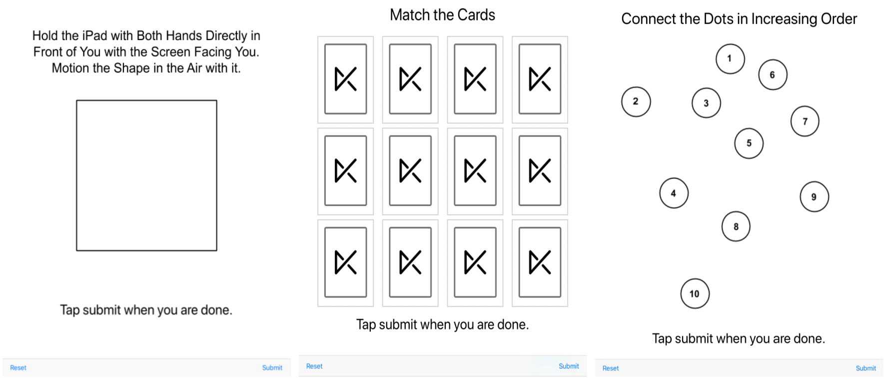

Fig. 2. Sample interactive views of gross motor, memory, and executive function tasks.

order. Finally, each of these tasks depicted visual feedback to the user from their interactions on the device screen (e.g., lines on the screen where the user has traced or the cards flipping and staying face up when matched).

3.4 Test Submission

Following the completion of any of the aforementioned tests (e.g., tracing the shape, emulating the shape, card matching, and trail making) the user is instructed to tap the submit button in the navigation bar in the bottom right corner of the screen. The submission button interaction denotes when the user feels they have finished the functional task based on the given set of instructions.

4 Methods

4.1 Usability

Participants were 40 adults between the ages of 52 and 84. These participants were divided into two groups; those with a confirmed diagnosis of Parkinson's Disease and age matched healthy controls. Participants were recruited through advertisements, physician and clinician referrals, spouses/caretakers of the diagnosed population, and prior studies in our laboratory. Inclusion criteria for the current study consisted of being age 50 years or older. Participants were excluded from the current study if they were unable to provide informed consent or if their native language was not English (as instructions and speaking tasks were all formatted in English).

All participants were required to complete the mobile versions of the tasks mentioned previously (e.g., tracing the shape, emulating the shape, card matching, and trail making) to gather objective metrics in the assessment of neurocognitive functionalities (e.g., using device sensors and screen interactions)

Table 2. Mobile device assessment features

Task type	Description	Utilized mobile device features
Fine motor	Tracing depicted shapes	User-screen interactions and timer
Gross motor	Device manipulation	Accelerometer, gyroscope, and timer
Memory	Card matching	User-screen interactions and timer
Executive function	Trail making	User-screen interactions and timer

(Table 2). Different task versions were completed to assess how to modify the overall assessment system for higher quality interactions. The test set included fine motor (e.g., tracing depicted shapes), gross motor (e.g., manipulating the device to "air"-trace a prompted shape), memory (e.g., card matching), and executive function (e.g., trail making) tasks. For usability, a focus was placed on observing user device interactions for updating the overall testing design (e.g., device task instructions and button placement).

4.2 Cognitive Interference

Since individuals with neurodegenerative conditions (e.g., Parkinson's Disease) demonstrate impaired functionality of both motor and cognitive tasks, multiple versions of each functional task were created (e.g., single and/or dual-task) to examine cognitive interference effects in mobile task design.

Single Task Interference. Single functional tasks of card matching and trail making were administered to all participants using two versions of each task.

Card Matching. Two versions of the card matching task prompt the user to match cards with different stimulus constraints. During each task the user must interact with only two cards per turn. If both cards match they remain face up and are out of play the rest of the assessment; otherwise, they are turned back over until the user matches the correct pair.

The first memory assessment (Version A) has the user match 6 pairs of cards where each pair is set to be a different shape and color combination (e.g., matching two *grey squares*, two *red triangles*, two *purple hexagons*, etc.). The second assessment (Version B) introduces visual cognitive interference. The protocol has the user match 6 pairs of cards where each pair has a different shape but only 2 colors (red and black) (e.g., matching two *red hearts*, two *red diamonds*, two *red stars*, two *black spades*, two *black clubs*, and two *black crosses*).

The overall time to complete the task (e.g., time from the user's interaction with the first card, until the last pair is matched) is collected for both versions of this test.

Trail Making. In two versions of the trail making task, the user must use their finger to draw a line connecting shapes in increasing order of numerical count.

The first trail making assessment (Version A) has the user connect the circles in increasing order from 1–10. The second assessment (Version B) introduces a visual cognitive interference. In this version the shapes are varied (e.g., circles, squares, triangles, etc.) as are their location and fill colors (e.g., white and grey). The protocol is maintained to have the user connect the shapes in increasing order from 1–10.

Metrics collected for both versions of this task include the overall time (e.g., the time from user start to user submit), the total number of points drawn, and the average distance from a true value point (e.g., the average distance between the closest point drawn by the user and the center point or *'true value'* of each numbered shape).

Dual-Task Interference

Fine Motor Function with Speech. Understanding how fine motor function is affected *with* speech, it is necessary to understand fine motor function *without* speech. In a fine motor task *without* speech, the user is prompted to interact with the device screen by tracing a shape (e.g., a circle) with their finger (Version A).

In the dual-task version of the assessment of fine motor function and speech (Version B) the user is prompted to trace the same shape shown on the screen while in tandem saying the months of the year, aloud, in reverse order (e.g., December to January). The reverse ordering of months without visual cues institutes a non-automatic task that increases cognitive interference.

Metrics collected for the single and dual-task approaches of fine motor testing include the overall time (e.g., the time from user start to user submit) and the total number of points drawn.

Gross Motor Function with Speech. Similar to the dual-task assessment above, an understanding of how gross motor function is affected *with* speech, it is also necessary to understand it *without* speech. The task version *without* speech (Version A) has the user manipulating the mobile device to "air"-trace a prompted shape (e.g., a square).

In the dual-task version (Version B) of this task the user is prompted to manipulate the mobile device for the emulation of the shape in tandem with the non-automatic task of saying the months of the year, aloud, and in reverse order.

Metrics collected for the single and dual-task approaches of gross motor testing include the overall time (e.g., the time from user start to user submit) as well as the average, maximum, and minimum magnitudes of the device's acceleration.

5 Results

5.1 User Interface

The usability of the testing setup was analyzed across all participants to understand the overall quality of the design (e.g., layout, instructions, and screen interactions). This analysis was intended to allow for updating the testing process for higher usability of individuals in diagnosed populations, specifically those with Parkinson's Disease.

The overall usability was assessed by gathering the number of incorrect screen interactions between groups. An *incorrect screen interaction* was denoted as any time a user interacted with the screen incorrectly in terms of navigation (e.g., clicking submit prior to completing the test), or by interacting with the screen in a way that was not depicted by instructions or demonstrations (e.g., tapping on the screen when drawing was required). Table 3 looks at the total number of incorrect interactions by group. Individuals in the PD group interacted with the testing application incorrectly more than individuals in the age-matched control group for baseline assessments (5.02% compared to 0.35%). Further, when a representative subset of individuals in the PD group were asked to take the mobile based assessment again (e.g., with the same test instructions given both verbally and via the tablet) there were still a higher number of incorrect interactions compared to the control group (3.15% compared to 0.35%).

Table 3. Overall frequency of incorrect screen interactions

Group	Number of tests	Number of incorrect interactions	Ratio
PD baseline	598	30	5.02%
PD 2nd visit	286	9	3.15%
Control	286	1	0.35%

5.2 Test Design - Cognitive Interference

Single Task Interference

Card Matching. The analysis revealed a significant difference in both task versions for the time taken to complete the task between both groups ($p < 0.05$) with individuals diagnosed with Parkinson's Disease taking longer than the age appropriate control group (Table 4).

Table 4. Card matching metrics

Metric	Mean (SD) or p-val
Version A (without interference)	
Time (PD)	64.43 (41.93)
Time (control)	36.54 (13.73)
T-Test	$p = 0.007$
Version B (with visual interference)	
Time (PD)	62.72 (51.47)
Time (control)	38.29 (17.10)
T-Test	$p = 0.048$

Trail Making. The analysis of both trail making task versions (Table 5) revealed a significant difference ($p < 0.05$) for the metrics of time taken, and total points drawn. The metric of the average distance (e.g., the average distance between the closest point drawn by the user and the center point of a numbered shape) in the task without visual interference (Version A) yielded a significant difference between the PD and control groups ($p < 0.05$) whereas the task with visual interference (Version B) did not ($p = 0.457$).

Table 5. Trail making metrics

Metric	Mean (SD) or *p*-val
Version A (without interference)	
Time (PD)	17.28 (4.68)
Time (control)	12.13 (2.26)
T-Test	$p = 0.011$
Total points (PD)	387.74 (143.94)
Total points (control)	293.67 (57.85)
T-Test	$p = 0.010$
Average distance (PD)	13.56 (3.11)
Average distance (control)	10.03 (3.92)
T-Test	$p = 0.008$
Version B (with visual interference)	
Time (PD)	18.38 (8.45)
Time (control)	11.67 (2.06)
T-Test	$p = 0.001$
Total points (PD)	370.87 (103.71)
Total points (control)	252.58 (38.56)
T-Test	$p < 0.001$
Average distance (PD)	12.85 (4.26)
Average distance (control)	11.76 (3.65)
T-Test	$p = 0.457$

Dual-Task Interference

Fine Motor Function with Speech. The analysis of fine motor metrics without speech found a significant difference ($p < 0.05$) between groups for total time, and total points was found. Similarly in the dual-task version, (e.g., assessing speech and fine motor function together) a significant difference ($p < 0.05$) between groups for overall time and total points drawn by the user was found. Overall individuals diagnosed with Parkinson's Disease in both single and dual-task versions took longer and interacted with the screen more (e.g., drawing more points) than those in the control group (Table 6).

Table 6. Fine motor metrics

Metric	Mean (SD) or p-val
Version A (without interference)	
Time (PD)	9.62 (5.26)
Time (control)	6.21 (1.17)
T-Test	$p = 0.007$
Total points (PD)	216.91 (94.77)
Total points (control)	146.83 (69.07)
T-Test	$p = 0.018$
Version B (dual-task interference)	
Time (PD)	14.41 (8.58)
Time (control)	9.51 (1.97)
T-Test	$p = 0.015$
Total points (PD)	515.78 (265.30)
Total points (control)	349.17 (80.06)
T-Test	$p = 0.010$

Gross Motor Function with Speech. The single task version of the gross motor functional task yielded a significant difference ($p < 0.05$) comparing the groups for total time. All other metrics collected (e.g., the device's average, maximum, and minimum magnitudes of acceleration) were found to be non-significant ($p = 0.796$; $p = 0.220$; $p = 0.058$, respectively). The dual-task version (e.g., assessing speech and gross motor function together) revealed a significant difference ($p < 0.05$) between groups for maximum and minimum magnitude of acceleration. The metrics of overall time and average magnitude of acceleration were found to be non-significant ($p = 0.180$; $p = 0.96$, respectively). Metrics and their respective significance values for all gross motor functional testing are seen in Table 7.

6 Discussion

6.1 User Interface

The disparity in usability between PD and control groups of incorrect screen interactions depicts that updates in the user interface design need to be completed. The number of user mistakes differed notably between groups in the assessment (e.g., 5.02% compared to 0.35%). Although experience and/or training can address some of the problems had by users (e.g., the number of mistakes from a representative subset of the PD group decreased in a secondary interaction of the assessment; 3.15%), the disparity between groups calls for updates to the application to create a more usable device for all intended populations. *Incorrect screen interactions* are denoted as any time the user interacted with the screen incorrectly in terms of navigation (e.g., clicking submit prior to completing the test), or by interacting with the screen in a way that was not depicted

Table 7. Gross motor metrics

Metric	Mean (SD) or p-val
Version A (without interference)	
Time (PD)	7.88 (3.05)
Time (control)	4.97 (1.31)
T-Test	$p = 0.001$
Average magnitude (PD)	1.00 (0.01)
Average magnitude (control)	1.00 (0.01)
T-Test	$p = 0.796$
Maximum magnitude (PD)	1.27 (0.20)
Maximum magnitude (control)	1.35 (0.14)
T-Test	$p = 0.220$
Minimum magnitude (PD)	0.78 (0.14)
Minimum magnitude (control)	0.68 (0.14)
T-Test	$p = 0.058$
Version B (dual-task interference)	
Time (PD)	9.05 (2.54)
Time (control)	7.98 (1.84)
T-Test	$p = 0.180$
Average magnitude (PD)	1.00 (0.01)
Average magnitude (control)	1.00 (0.01)
T-Test	$p = 0.96$
Maximum magnitude (PD)	1.19 (0.14)
Maximum magnitude (control)	1.32 (0.17)
T-Test	$p = 0.033$
Minimum magnitude (PD)	0.832 (0.104)
Minimum magnitude (control)	0.725 (0.119)
T-Test	$p = 0.017$

by instructions or demonstrations. Those processes in the user interface design need to incur changes to reduce the number of incorrect instances of the diagnosed population. The following subsections discuss methods of updating the application to address both task instructions (e.g., re-watchable demonstrations) and navigational components (e.g., button placement) to help mitigate incorrect screen interactions.

Test Layout. Figure 3 shows a depiction of the updated fine motor functional tracing test version of the assessment for both instructional views and interactive views. Figures 4, 5, and 6 shows the updated gross motor, memory, and executive function test views. These updated test layouts allows for separated material

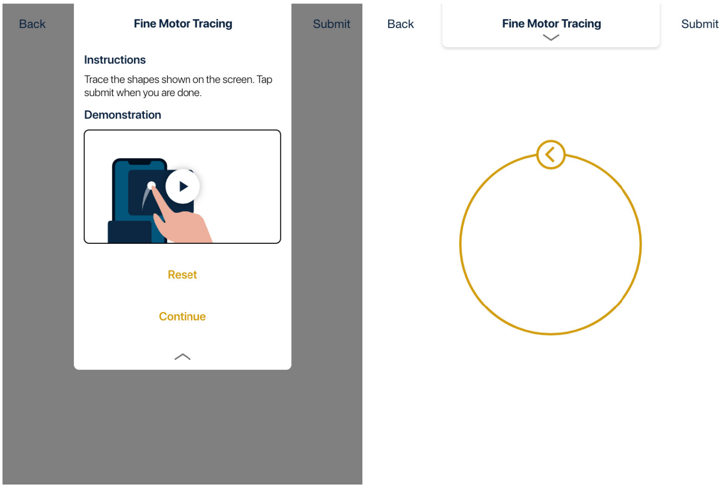

Fig. 3. Updated instructional and interactive views of a fine motor functional tracing task.

(e.g., moving the instructions to a separated screen from the interactive view) while allowing for all test instructions to be viewed by the user at any point in time through the inclusion of a drop down menu.

Test Instruction. Testing instructions for the updated versions can still be given to the user verbally (e.g., by a test proctor or clinician) and via the tablet (e.g., written in short texts in common language). The updated version also includes a video demonstration of the functional task compared to a static partial demonstration in the previous versions. Figure 7 is a depiction of this video demonstration for the fine motor tracing test where a sample shape is being traced by an animated index finger in the required direction in its entirety. These videos can be played multiple times to allow the user to understand the test completely prior to their interactions. On the interactive screen for certain tests, a smaller prompt (e.g., a small circle with an arrow pointed in the direction of intended interaction) is shown to give users a starting location and direction as described in the video demonstrations.

Test Interactions. Updates to the testing layout were also completed to enhance user test interactions. The updates of moving all buttons to the top of the screen are to help mitigate incorrect screen interactions including clicking submit prior to completing the test. Although device users prefer and perceive bottom bar navigation menus better than other types (e.g., hamburger menu), populations with motor impairments show to have unintentional interactions near the edges of the screen closest to their dominant hand (e.g., clicking submit prior to being done with the functional task). Similarly, removing the

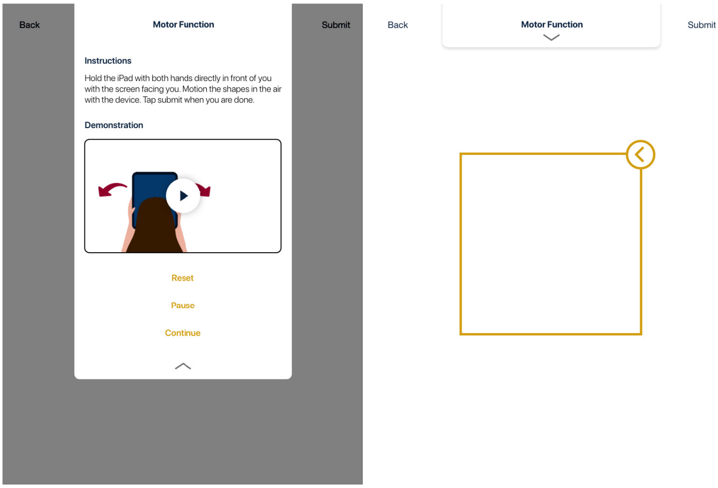

Fig. 4. Updated instructional and interactive views of a gross motor task.

instructions and bottom navigational bars allows for the user to have more room for interactions on the screen while maintaining desired functionality.

6.2 Test Design

Since individuals with Parkinson's Disease demonstrate impaired functionality of both motor and cognitive tasks, multiple versions of each functional task were created (e.g., single and/or dual-task) to examine cognitive interference effects in mobile task design. The following subsections discuss the potential benefits of these different versions for the implementation in mobile assessment instruments.

Card Matching. Memory function metrics from both versions of the card matching task showed that either task could be implemented in the formation of a new testing suite. There were no significant differences in time between the card matching tasks *with* or *without* visual interference in the case of reducing the number of unique colors from six to two for the PD group ($p = 0.902$) or control group ($p = 0.785$). Therefore either task version, A or B, could be implemented to gather necessary timing metrics for memory function of individuals with PD. An updated depiction of the card matching task is shown in Fig. 5.

Trail Making. Version B of the task showed a difference for control groups compared to its non-interference counterpart, specifically for the metric of average distance (e.g., the average distance between the closest point drawn by the user and the center point or *'true value'* of each numbered shape). The desired outcome of configured tasks is the formation of a version that separates the groups maximally (e.g., yields the highest number of significant metrics between

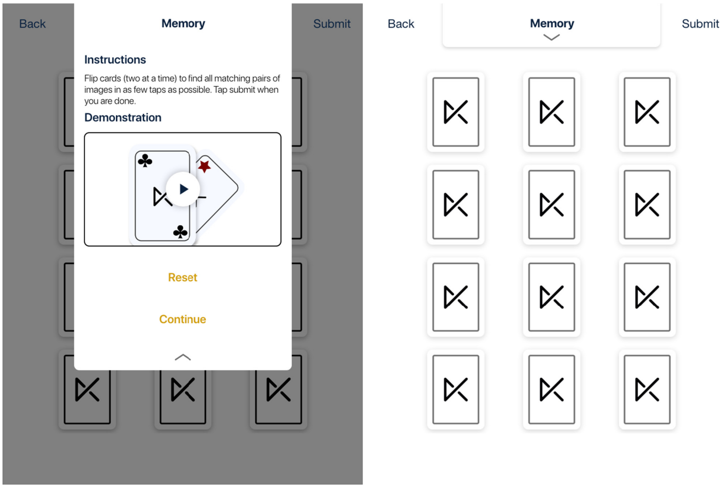

Fig. 5. Updated instructional and interactive views of a memory based task.

groups), therefore the implementation of Version A (e.g., having the user connect circles in increasing order from 1–10) should occur as Version B does not provide the maximum separation of the PD and control groups. An updated depiction of Version A is seen in Fig. 6.

Fine Motor Function with Speech. Fine motor function metrics from both singular and dual-task versions show that either version of the task could be implemented in the formation of a new testing suite, however unlike the card matching task, there are benefits to both. Version A of the fine motor task (without dual-task interference) has a significantly shorter duration than the dual-task version ($p = 0.028$ and $p < 0.001$) when comparing the PD and control groups across versions. In the formation of a dual modal task (Version B), additional information can be collected with the configuration of mobile device sensors and capabilities. As the participant is required to speak aloud during Version B of the test, the device's speech recognizers can be implemented for the accuracy count of words said. Further, audio recordings of the speech sample can be made for the subsequent analysis of frequency measures. An updated depiction of Version A is shown in Fig. 3 and Fig. 8 for Version B (dual modal).

Gross Motor Function with Speech. The collected gross motor metrics, from singular and dual-task versions, show that both are needed for the collection of significant, objective metrics. Having participants do either Version A (without dual-task interference) or Version B (with dual-task interference) alone, removes significant and objective information on the state of the person being assessed. In new testing suites, gross motor function in a dual-task versions should be added.

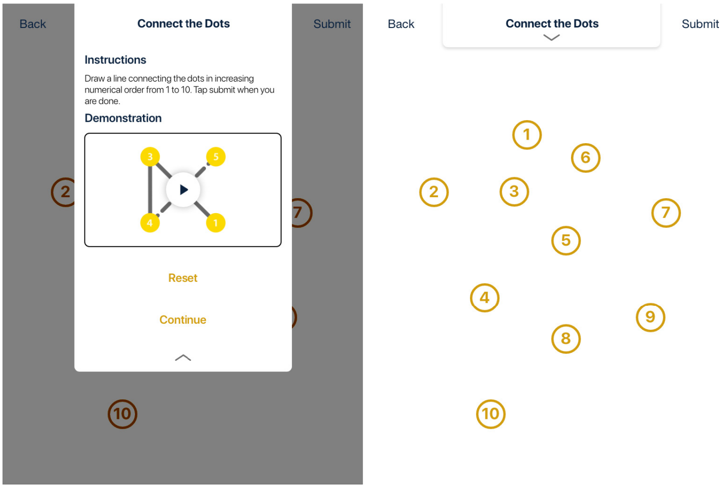

Fig. 6. Updated instructional and interactive views of an executive function based task.

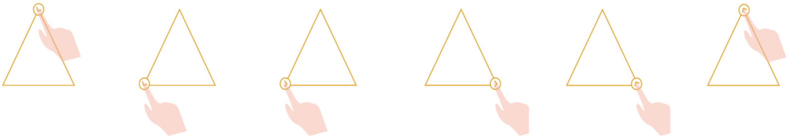

Fig. 7. Animation of fine motor tracing instructions.

An updated depiction of Version A is shown in Fig. 4 and Fig. 9 for Version B (dual modal).

Comparing Interference Types. Interference types may have different effects on overall cognitive function during assessments. Sensory interference (e.g., visual, auditory, and tactile) can be implemented as distraction mechanisms during tasks where the main goal is to see if users can minimize these distractions and complete the task at hand. Multifunctional tasks can be implemented to help understand prioritization strategies of the required tasks. Instances of tasks with fine motor components were modified to implement both sensory interference or dual-task interference. In the single modal task with visual interference, there was a decrease in the number of significant metrics collected as the difference between PD and control groups for the metric of average distance was non-significant. In a dual-task version of task interference the collected fine motor metrics remained significant and there is also the potential for a variety of other metrics to be collected. In the formation of new functional testing assessments, the implementation of the dual-task version should be added due to the collection of additional relevant metrics, unless there are impending time constraints.

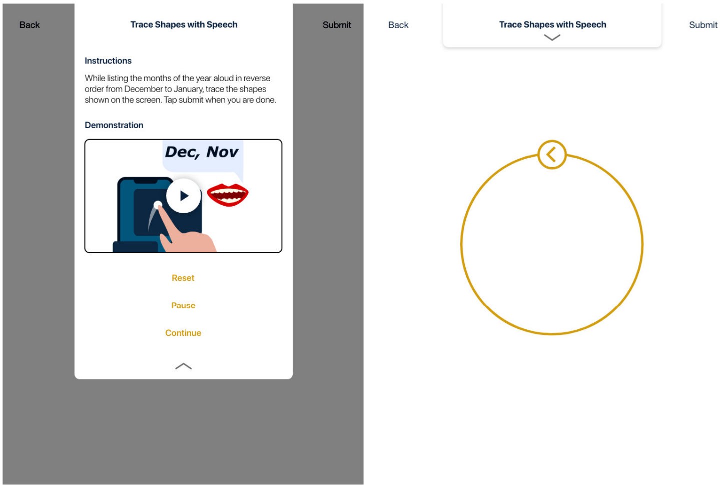

Fig. 8. Updated instructional and interactive views of a dual modal fine motor task.

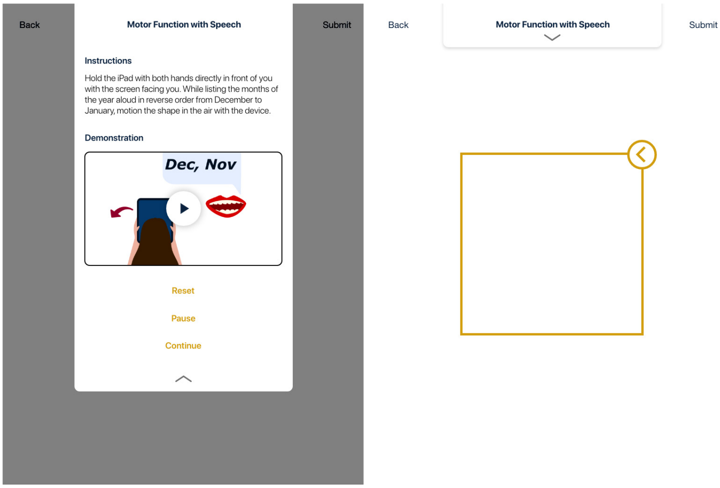

Fig. 9. Updated instructional and interactive views of a dual modal gross motor task.

Interference Modalities. Although visual interference (e.g., single task interference) and motor and speech dual-task interference were monitored in this study, there are additional ways to implement cognitive interference into testing platforms. Extensive interference processes could also be completed in the case of tri- or multi-task interference (e.g., having the user engage in three or more functional areas of interest at one time) or compounded task interference (e.g., increasing interference signals over the course of a test). Similarly, multi-functional assessments could implement one or multiple sensory interference(s) for the simulation of more real world scenarios (e.g., walking and talking with implemented sensory stimulus).

For individuals with Parkinson's Disease, visual cognitive interference in both memory and executive function did not provide additional significant metrics compared to control groups. In dual-task cognitive interference, fine motor function maintains significance for all explored metrics but ultimately allows for the collection of speech samples for further analysis and expanded metric sets. Dual-task interference for gross motor function showed varied significance metrics compared to a non-interference version. In this capacity, the use of both task versions allows for the collection of additional, relevant, and objective metrics.

7 Conclusions and Future Work

Mobile devices are becoming more prevalent in the monitoring of individuals' health in many capacities. Based on the findings in this study, a focus should be given to updating mobile assessment instruments for both usability and task performance. This should be done by changing layouts to minimize incorrect interactions (e.g., moving submission buttons, making locations for screen interaction much clearer/understood), while maintaining all necessary instructional information such that the user understands the functional task. Although healthy populations tend to be able to interact with various features across many applications, overall application development should focus on all possible users. With regards to the mobile neurocognitive assessment systems; the configuration of devices and user interactions for an aging population across diverse abilities and conditions is necessary for the monitoring of individuals task performance and can yield the highest usability and accuracy across all groups. This can be completed by updating overall user interface design, specifically testing instructions, layouts, subsequent user interactions, and task configurations. In the formation of relevant and objective task configurations, for various progressive and acquired neurological conditions, an understanding of how cognitive interference plays a roll is necessary. Different implementations should be explored to understand when cognitive interference is beneficial in different neurological task versions. This should be done across all functional neurocognitive areas of interest and against an extensive set of configurable device metrics. The understanding of new interference modalities can further aid in the formation of comprehensive assessments for all neurological conditions. Other conditions including stroke, dementia, or traumatic brain injuries may call for different user device configurations and/or different cognitive interference types across digital tests for the collection of important objective metrics. Ultimately, the formation of usable mobile neurocognitive assessment systems for digital testing can assist in the understanding of new relevant, objective, and significant metrics. Further understanding of the usability of mobile devices for individuals with neurological conditions in addition to the implementation of cognitive interference to address task performance may allow for the increase in accuracy for both diagnostic and rehabilitative monitoring purposes for all neurological conditions.

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