Development of an Online Application that Enables Older Adults to Self-assess their Driving-related Cognitive Ability

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Our cognitive abilities can change as we age and these changes may reduce our ability to perform day to day activities, one of which is driving. Older adults with mild cognitive impairment or mild dementia have been shown to have higher number of crashes per mile driven and are more vulnerable to injuries due to frailty. Driving cessation, however, not only curtails mobility, but can cause social isolation and depression among older adults; this is especially true in countries like Canada that have relatively long driving distances and dependency on cars for transit. Driving is often synonymous with independence and hence any discussion about it requires careful consideration by physicians, family, and most importantly the drivers themselves. Motivated by the need to balance road safety and autonomy, this study aims to create and evaluate *SmartDrive*, which is a digital application that helps refocus the discussion about driving in a way that empowers the older adult. Developed using participatory design methods, *SmartDrive* is an online, self-assessment application that implements a collection of validated cognitive tasks that have been correlated with on road driving performance namely, Trail Making Test (Part B), Porteus Mazes & Useful Field of View (subdivided attention). The objective of *SmartDrive* is to provide the older adult with accurate and useful feedback on their driving-related cognitive abilities in order to promote informed and safer driving decisions.

The results from iterative testing of *SmartDrive* indicated a high acceptance of the app among older adults. The primary motivator for using the app was the need to monitor age-related cognitive decline and its effects on safe driving. Qualitative analysis of the semi-structured interviews conducted with 24 older adult drivers revealed themes that captured the preferred design features and underlying user characteristics that influenced the adoption of *SmartDrive*. The themes and sub-themes that were identified in this research contribute to the current usability frameworks and can be used as a guide for development of other web-based applications that support older adults in self-assessment and periodic monitoring of different skills.

Acknowledgements

This work would not have been possible without the support of many people and on the very top of that list is my supervisor. I would like to thank Dr. Jennifer Boger for guiding me through this project and constantly introducing me to new design perspectives. Thank you for moulding my 'I want to solve everything' intention into practical research questions and study protocols. I believe I've come out a better designer than I went in because of our discussions. Thank you to Dr. Siby Samuel for introducing me to a truly interesting and challenging project and for mentoring me through my first year.

I would like to thank Dr. Howcroft and Dr. McAiney for being my thesis readers, I appreciate your feedback and comments to help improve my research.

I would especially like to thank Dr. Howcroft for her feedback on the early designs of the app and her unique perspective on driving and dementia, her inputs helped shape the application's interface and the study design. I enjoyed working with Dr. Howcroft in the capacity of her teaching assistant over the terms. The experience taught me a great deal about human factors in design which I was able to apply to my thesis.

I'd like to thank the research support at Posit Science, their help was crucial in understanding the design of the cognitive tests. I am thankful to the members of the Game Dev Club at UW who helped me learn Unity from scratch. Thank you to James for helping me de-bug my code amidst a pandemic, and I am indebted to Apery for helping me with numerous participant calls, meetings and all those little things without which there would be no data. Thank you to all my participants for your honest opinions, our discussions made for an excellent learning experience.

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Finally, thank you Mom, Dad, BMax and Moti for always being patient and supportive over the years.

Dedication

To Lew, for his many great ideas.

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Chapter 1

Introduction

Driving is considered synonymous to independence by many. It provides us with a means of mobility to acquire essential products and services. It allows us to commute to work to earn a living. It is a way to stay connected with our communities, attend social events, and pursue our hobbies. It comes as no surprise that driving cessation in older adults has known to cause social isolation, depression, and even morbidity [22]. With distances often being quite far in North America, those in rural areas are required to drive a long way for basic needs such as groceries or medical services [62].

Driving is a complex task that demands different cognitive and physical abilities [45]. As we age, some of these faculties tend to decline. This effect is reflected in slowing of reaction times, loss of visual acuity and/or memory and diminishing proprioception (i.e., the ability to perceive relative position and distances) [1]. A study done by Vichitvanichphong et al. [101] examined the effects of these deficits on driving ability. Older adults were more likely to make errors in specific driving tasks such as lane keeping, speed control and navigation. A review of the crash statistics revealed a higher no. of crashes per mile driven in drivers above 65 years [34] (this demographic was found second highest in crashes after the 16-25 years category). Those living with mild cognitive impairment or mild dementia were observed to continue to drive up to 3-4 years after diagnosis [54] and had a crash risk of 2-8 times that of their age-matched controls [41] [83]. The risk for older adult drivers in these motor vehicle crashes is higher since they are more vulnerable to injuries due to a higher likelihood of frailty which has accounted for 60-95% of

the excess death rates per mile driven in older drivers [63].
While the current system in Ontario, Canada involves driver re-licensing tests (cognitive/knowledge tests) every two years after the age of 80 [54], it does not provide any interventions in the decades between acquiring a license and reaching the age of 80. For those living with cognitive impairment such as Alzheimer's disease or another form of dementia, their physician is legally obligated to report any issues they've identified that can affect the driving ability of the older adult [54]. Studies have reported several drawbacks in the current system. Firstly, decline in older adults' ability to drive varies from person to person [49], which questions the efficacy of a 'one-size-fits-all' approach for re-licensing procedure. Secondly, studies have observed a lack of knowledge and training for driving fitness assessments amongst clinicians [55]. Some were even reported to be unaware of the protocols that should be followed [60]. Physicians are also reluctant in initiating a discussion about driving with dementia because of their belief that there is no treatment for dementia that can be offered to the patient [100]. A significant stress on the physician-patient relationship was also observed due to the uncomfortable yet necessary discussions about driving cessation and the negative impact it has on the independence of the older adult driver [22].

The objective of this research was to design a way for older adults to privately assess and periodically monitor their driving-related cognitive ability. This is in order to empower them with information to support conversations regarding their driving and advance planning for their driving futures to make independent yet safe decisions. Motivated by a much needed balance of road safety and personal autonomy, this research focused on the design of a digital application that can engage the older adult driver in critical conversations about their driving without a fear of revocation of license impeding the process.

1.1 Research Objectives and Questions

The research presented in this thesis focuses on the development and testing process of *SmartDrive*, which is a self-assessment application that is aimed to support older adults in understanding their driving ability and promoting safer driving decisions. The goal

of this thesis is to leverage participatory design methods, technology acceptance models and different qualitative analysis frameworks to:

- co-develop a user-centred digital application for older adults to self-assess their ability to drive safely;
- iteratively evaluate and redesign to improve the engagement, usability, usefulness and overall user-experience of the application, and;
- explore persuasive features that can be included in the application to promote safer driving decisions and prompt early planning for driving cessation.

The five research questions guiding this thesis have been listed below; the breakdown of the three development and testing stages to answer these questions are illustrated in Fig 1.1.

1. How do older adults perceive a driving self-assessment application that is based on cognitive-testing?
2. How accessible and navigable is the interface of the application for older adults?
3. How can feedback from cognitive tasks be presented to older adults in a way that promotes critical thinking about driving followed by safer driving decisions?
4. What impact does the feedback and recommendation provided by the application have on the user's self-perception of driving?
5. How can the application prompt the user to plan for their driving future, including possible driving cessation?

To answer Research Question 1, the reception of a driving self-assessment application among six older adult drivers was explored. After a prototype was developed (Stage 1 in Fig 1.1), a pilot study was designed (Stage 2 'Pilot Study' in Fig 1.1) to gauge immediate reactions and get feedback on the pilot version of *SmartDrive* from six older adult drivers.

Following the analysis of feedback received from pilot-testing (See Fig 1.1 Stage 3), the pilot version was redesigned and improved in the subsequent version (i.e.,*SmartDrive 1.0*). The usability study evaluating this version focused more on investigating the usability and usefulness of *SmartDrive 1.0*. Research Questions 2 & 3 were explored through the 'Main Study' (See Fig 1.1 Stage 4) using online interviews with 16 participants in Phase-1 of Stage 4. After analysing the data from the 16 interviews, the design was further revised to produce *SmartDrive 2.0* and this was tested with eight participants in Phase-2 of Stage 4. Additionally, to explore Research Questions 4 & 5, the lasting impact of the user's experience with the app was explored with a focus on the idea of advance planning for if and when driving cessation should occur.

1.2 Thesis Organisation and Contribution

Table 1.1 shows the organisation of the chapters in the thesis and their description.

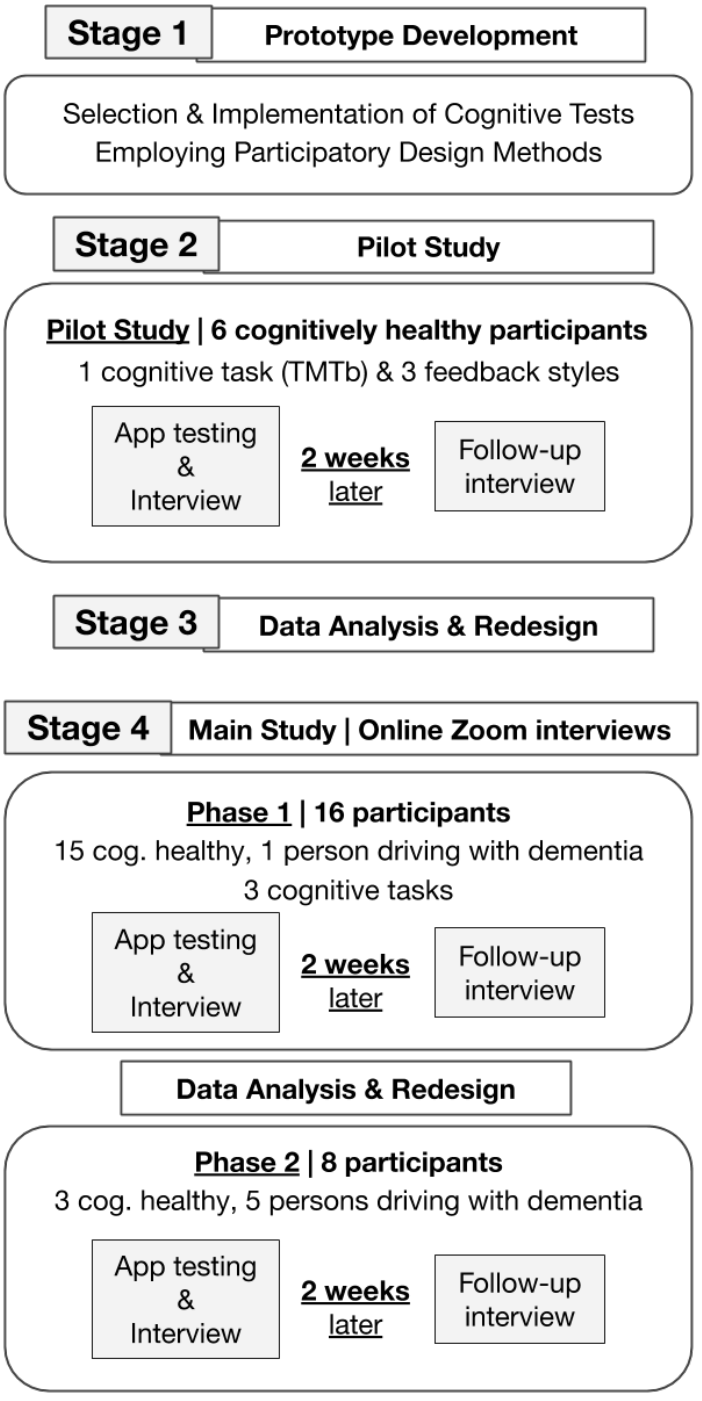

Figure 1.1: Flow of different development stages of SmartDrive

Table 1.1: Thesis Organisation

Chapter	**Description**
1. Introduction	Research motivation, research questions, thesis organisation and contribution
2. Background	Literature review of driving with dementia, cognitive testing as a driving screening tool and other assessment applications.
3. Development of a Prototype	Selection of cognitive tests, Implementing Persuasive Systems Model and participatory design methods.
4. Piloting a Prototype	Study design, results and of preliminary evaluation of the prototype
5. Testing *SmartDrive 1.0 & 2.0*	Study design, results and discussion of pilot evaluation of the prototype
6. Overall Discussion	Overall findings of thesis research and their implications
7. Conclusion	Contributions to digital design for older users and driving assessment fields and future research opportunities.

Chapter 2

Background

This chapter provides an overview of literature related to driving and dementia. The author discusses the effects that age-related cognitive decline and symptoms of dementia have on safe driving. The importance of driving as a means of mobility and the negative effects of driving cessation on the well-being of the older adult are also examined. The limitations of the current system of re-licensing procedures are discussed and the benefits and importance of advance planning for driving cessation are described along with its adoption in the dementia-care sector.

2.1 Driving and Dementia

Driving is popularly viewed synonymous to independence. It provides us with mobility to pursue our hobbies, to socialise and more importantly obtain essential goods and services, such as food and healthcare. It therefore is not unexpected that studies have found that older adults who have stopped driving have shown signs of social isolation, depression and morbidity [40], [25]. The activity of driving is challenging and has a high visual and cognitive demand; it engages several different cognitive functions at once such as quick processing speed and reaction time. Broad central and peripheral visual fields are also necessary in hazard perception. These have been noted as some of the crucial visual and cognitive skills one needs to safely drive a vehicle [29]. Studies have shown that

age-related cognitive decline can have permanent effects on some of these driving skills [7], [93]. A study by Vichitvanichphong et al. examined specific driving errors that older adults were more likely to make due to age-related cognitive decline, they found that older adults had difficulty in lane keeping, speed control and decision making [101]. It is important to note that drivers above 65 years have a higher crashes per mile driven rate [34].

Dementia is commonly defined as loss in multiple cognitive functions such as memory impairment, decline in language and abstract thinking [11], can significantly affect driving performance, with an increasing impact as dementia-related symptoms worsen over time [94]. However, older adults living with dementia (Alzheimer's type with an average disease duration of 10 years) have been observed to continue driving up to four years after onset of symptoms [54]. Crash risk in those with dementia (Alzheimer's and vascular dementia) is two to eight fold higher than that of their age matched controls [47]. Older drivers are also most vulnerable in motor vehicle crashes due to their fragility [63].

Hence the answer to a crucial question that concerns older adults: "When do I hang up my keys?" becomes one of a good balance between Autonomy (i.e., the independence of mobility that is crucial to the older adults' well being) and Safety (i.e., the responsibility of the individual and the community to ensure safety of all drivers on the road).

2.1.1 Advance Planning for Driving Cessation

Positive effects of planning are well known and can be addressed from a psychological perspective. In general, planning helps us free up cognitive resources that we could allocate for other tasks and can help reduce anxiety about upcoming decisions [42]. It has also known to inspire a conscious effort in the process and supports the person to engage in a more sustainable and appropriate behaviour when they have a broader range of choices available to them [24].

'Advance Care Planning' (ACP) is a popular process physicians and those living with dementia are encouraged to apply. ACP supports the idea of sharing the person living with dementia's (PWD) values, goals and preferences with their families and healthcare providers to ensure that consistent care is received during the later stages of the illness [96]. A similar approach for transportation and planning has been explored for those

driving with dementia [61]. Physicians are constantly encouraged to have routine discussions with their patients to identify the effects of dementia on driving and take an active approach in mitigating risk [2]. Another study framed the idea of transport planning as a collaborative process between physicians, patients and their families [78].
The benefits of advance planning for driving cessation have been observed in many studies. It has been shown to help older adults in seeking community support for mobility in a timely manner [64]. It has been noted as an effective process in facilitating smoother transition to driving cessation [65]. Interventions due to advance planning for driving cessation have reduced anxiety related to driving concerns in retired drivers and have been noted to improve the general well being of older adults [65].

2.2 Driving Assessment Applications

Several driving guides and programs are currently available for any older adult looking to assess their driving. CAA's Simple Driving Assessment (See Appendix N) and AAA's Drivers 65 plus Self-rating questionnaire (See Appendix J) are both based on 15 questions that engage the older adult drivers in a self-evaluation of their driving habits (e.g., wearing seat belts, vision check-ups etc.). At the end, the scoring system classifies their set of responses into one of three categories: Go, Caution and Warning. Suggestions and explanations for the 15 questions are provided at the end of the brochures for the user's reference. British Columbia Traffic Safety Foundation offers a Safe-driving checklist that helps the user identify safe practices of vehicle maintenance, speed, steering, and other elements.
While question-based checklists and evaluations can be informative, they are based on an "honour code" of truthful responses and can be inaccurate since the user's realistic ability to drive safely is not verified. Other knowledge-based assessments directed towards younger driver's licensing programs to pass G1 and G2 driver's tests in Ontario are available online but do not include skill-assessment. These applications typically include a series of pictures of situations that one might come across on the road. The user must be able to comprehend the situation and select the right option reflecting their response to that situation. Percentage scores are presented at the end of this evaluation depending on the selected responses. These assessments are certainly stronger than passive ques-

tions but focus more on knowledge and awareness of speed limits and traffic signs rather than cognitive and physical abilities that need to be evaluated to assess overall driver safety [8]. An application that has been scientifically reviewed and is available online is DriveSafe & DriveAware (DSDA) [59]. DSDA is a screening tool designed for clinicians and patients to support in screening for fitness to drive. This tool includes three sub-tests mainly focusing on presenting intersections and asking the user to detect object's location, movement and direction. This application includes an intersection-rules and knowledge test but does not assess cognitive or physical abilities that are crucial to perform on-road driving related tasks safely.
All the applications mentioned above are certainly useful in identifying and mitigating risky behaviours by providing information to the user to address lack of safe driving practices or lack of knowledge about traffic signs and rules. However, they fail to provide the user with a metric that reflects their current state of driving skill and safety, an essential aspect which has been acknowledged by a few other applications as explained below.

2.2.1 Cognitive Testing

The gold-standard for assessing driving capacity is an on-road test, but short of that, cognitive tests have been used commonly as a proxy [68]. The MTO's (Ministry of Transportation of Ontario) licensing procedure includes two on-road driving tests. However, for re-licensing as one reaches the age of 80, only cognitive and vision testing is widely used in re-licensing centres to measure driving ability [54].

Currently, physicians are obligated to report to the MTO any medical issues they observe that can potentially affect the patient's ability to drive safely [54]. Physicians commonly use their patient's performance on cognitive tests as a screening metric for their reports and with good justification [46]. Multiple studies have showcased the efficacy of these cognitive tests in predicting risk of crashes or scores on on-road driving tests [95], [23], [57]. The design of these tests allow for evaluation of essential cognitive domains such as: memory, information processing speed, executive function and vision, all of which have been shown essential for driving safely [8], [10].

MMSE (Mini Mental State Examination) and MoCA (Montreal Cognitive Assessment) have been popularly used for quantitative evaluation of cognitive impairment and

its severity, specifically for a diagnosis of Alzheimer's or other types of dementia [97], [71], [90]. MMSE and MoCA tests have shown correlations with on-road driving performance and are used as one of the metrics by the MTO for driving assessment as well as by physicians as a part of screening process for driving fitness [102], [56]. These tests are 10-minute questionnaires that involve memory, naming, visuo-spatial and other cognitive skill based questions (See Appendix P, Q). While the MMSE and MoCA have been used to estimate cognitive abilities, they were not designed to be used to determine driving abilities.

The CDR scale (Clinical Dementia Rating) has also been studied for its use in determining crash-risk especially for a driver living with dementia [76]. Other cognitive tests such as Blessed Dementia Scale, Boston Naming Test and Benton Copy, have been studied as a screening tool for dementia but conclusive correlations to driving fitness have not yet been established [80], [81]. Trail Making Tests (Parts A & B) [33], [9], Useful Field of View [26], [43] and Mazes [75], [74] have consistently shown significant correlations with different aspects of on-road driving. The studies that have examined the predictive ability of these three tests and their connection to driving is discussed in Section 3.2.

While general cognitive assessment applications such as BrainHQ (developed by Posit Science) and Lumosity (developed by Lumos Labs) implement cognitive testing, they do not specifically address driving related tests and skills. CogniFit [18] is another popularly used application that is based on validated cognitive tests showing correlations with on-road driving performance. CogniFit is an online program designed to enhance one's cognitive skills, it also includes a driving-related battery of tests (DAB) that young drivers, seniors or physicians can use to assess their driving fitness but is expensive (50 USD per session) and is a 40-minute long session.
DriveABLE products have also been widely used by clinicians to assess driving fitness in medically at-risk drivers [31]. Their two products, DriveABLE Cognitive Assessment Tool (DCAT) and DriveABLE On Road Evaluation (DORE), have been accepted by the medical community for screening driving fitness. While DCAT is based on six cognitive tests (that have shown accurate predictions of on-road driving), it is administered by the DriveABLE agency and the results are automatically sent to the patient's doctor for analysis. DCAT is an on-road assessment that is designed for clinicians or occupational therapists to evaluate driving fitness in older drivers.

What is missing is a way for older adults to privately assess their own driving ability whenever they wish from the comfort of their own home. This would help foster self-introspection and critical thought about their driving to make independent and safe decisions about their driving without a fear of revocation of license impeding the process.

2.3 Chapter Summary

This chapter discussed the effects that age-related cognitive decline and symptoms of progressive dementia can have on driving safety. The major limitations of the current re-licensing procedures are discussed namely, (1) lack of training among physicians to assess driving fitness [55], and (2) lack of individual screening to address the differences in cognitive ageing among older adults [49]. While driving and dementia tool-kits [20] and programs that are based on knowledge tests provide the older adult with useful information, the need for a practical and private skill-based assessment is reviewed. The validity of cognitive testing as a method of assessing driving ability is examined. Studies illustrating the significant correlations between cognitive tests and on-road driving have been described and the reasonable capacity of these tests to predict at-risk older adult drivers has been established [67], [50], [43] [89]. Cognitive screening for driving fitness is common practised by physicians [46] and applications designed for medical professionals (DriveABLE: DCAT and DORE [31]) are reviewed.

The choice for a private self-assessment of driving abilities so the older adult can make independent yet safe driving decisions had not been addressed in literature. Central to this was the need to enable older adults to engage in critical thought about their driving and advance planning for driving cessation. This was to promote safer driving decisions to potentially reduce crash risk among older adults and to support an easier transition to practical alternatives to driving while maintaining the autonomy of the decision for if and when driving cessation must occur.

Chapter 3

Development of a Prototype for the Self-Assessment of Driving Abilities for Older Adults

3.1 A Self-Assessment Tool

As identified in the previous chapter, there is a need for older adults to self-assess their driving in a non-threatening way. This is the basis for the research presented in this thesis; namely, the creation of a prototype to support older adult drivers in understanding their abilities better so they are equipped to make informed, independent and safer decisions about their driving. The aim was to provide the user with information to empower and centre them in thinking about and discussing their own driving. The design was to promote independent assessment that is self-administered by the older adults themselves. This was to address the need for control in their lives that older adults often feel they lose as they age [85]. This was also to reduce the burden that the caregivers often feel in order to initiate a difficult conversation about driving cessation [66].

There were three main aspects of the prototype that were addressed in the Stage 1: Prototype Development (See Fig. 1.1) stage of this application:

1. Assessment method: Cognitive testing

2. Co-design using participatory design methods

3. Usability of the interface: Design, Language and Layout

The prototype was centred on a set of cognitive tests that were selected and implemented as is explained in Section 3.2, followed by the participatory design methods used throughout the development process (Section 3.4), and lastly the models that guided the design of the interface to improve the readability and navigability of the design are described along with screenshots of the initial prototype (Section 3.5).

3.2 Assessment Method: Cognitive Testing

As mentioned in the previous chapter, several cognitive tests have shown a range of correlations with on-road driving performance. Following a review of the literature, three cognitive tests were selected with careful consideration regarding their applicability to the proposed driving assessment app to be created in this thesis work. Namely, five criteria were compiled for the selection of tests from those that were reviewed, the test/task should:

- maintain a correlation with on-road driving;
- have a design that allows digital replication of the the test test using the available software (Unity 2D Game Engine);
- be realistic to develop within the time-frame of an MASc thesis;
- be interactive and engaging to the user; not take longer than 5 minutes each in order to ensure a shorter overall assessment time;
- and can be administered without assistance from a physician or a family member while ensuring the validated protocols of the test procedures are preserved.

MMSE, MoCA and a few other cognitive tests mentioned in Section 3.1 satisfied only the first condition in our list. They could not be digitally developed within the time-frame. They were questionnaire-type tests while the application sought game-like tests to

make the application more user-friendly, engaging and non-threatening. Both tests were also longer than ideal i.e. took 10-15 minutes long. Commercially available, electronic versions of these tests were not suitable for this study due to the following reasons:

- The ability to tweak the application was essential in order to implement the usability features that were discussed with our community partners. To allow for this flexibility in design to use non-judgemental wording, simple layout, the design had to be built independently by the researchers.
- In order to provide a seamless user-experience that did not involve opening and closing different programs with inconsistent styles, language and colour schemes. Those that could be designed consistently were selected.

Considering all the criteria listed above, three tests were selected: Porteus's Five Mazes, Trail Making Test (Part B) and Useful Field of View (Subdivided attention). These satisfied all our conditions. Each of the tests have been explained in the following subsections along with the activity they entail and the method of implementation used for *SmartDrive*.

3.2.1 Porteus Mazes

Mazes have been observed in studies to have the potential to measure psychological planning and foresight, similar to what we need for driving safely during navigation [74]. Several studies have examined and confirmed the capacity of maze tests to predict on-road driving performance [74], [75]. Snellgrove's mazes among many have been examined for their significance in predicting ($p < 0.055$) those who passed or failed the on-road test [91], [23]. Porteus's mazes have also shown high correlations with on-road driving performance and the author selected a subset of five of these mazes for implementation in *SmartDrive* application as the completion time of these has been correlated with driving risk [92].

Activity Description:

Porteus's Mazes entail several mazes of varying complexity. Five mazes in particular have shown high correlations with on-road driving [92]. These five mazes were digitally implemented. These were initially designed as a pen and paper task where the person is asked to start navigating through the maze from a starting point without removing their pen from the paper to the finish point. The combination of both planning time (amount of time that the person views the maze and decides on a path) and completion time (time taken to draw the chosen path on paper) of all five mazes has been shown to correlate with driving [74].

Digital Implementation:

The author designed the digital version of this test using a circular dot to aid in navigating through the maze, where the users are asked to drag the dot from the start point to the finish point. Fig. 3.1 shows the mazes that were digitally designed and used in this research.

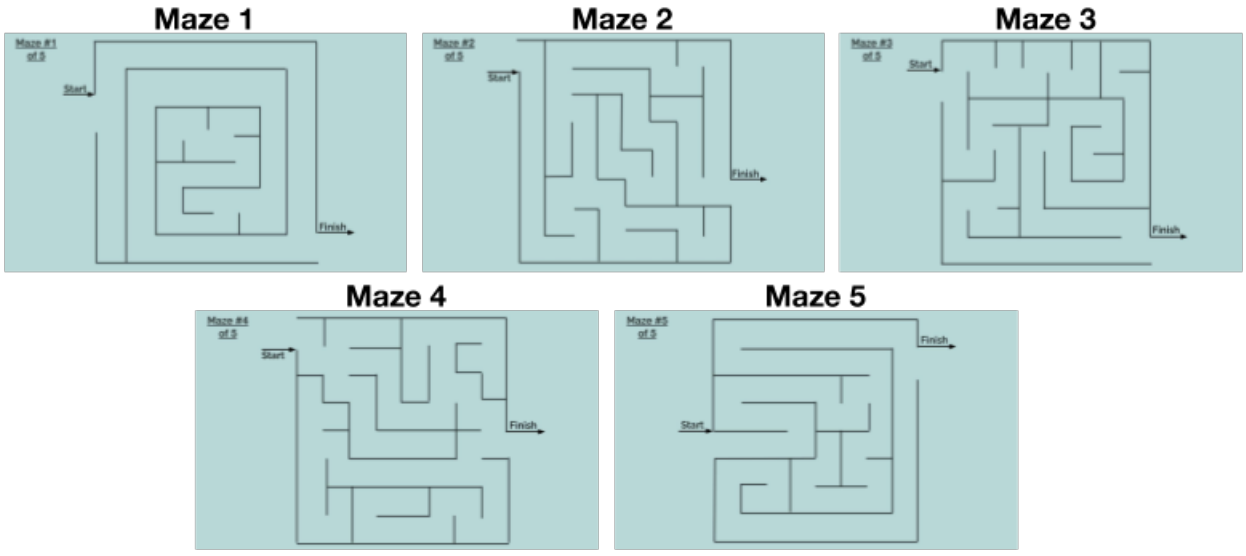

Figure 3.1: Screenshots of the five Porteus mazes that were designed by the author and presented to the user consecutively one after another in *SmartDrive*.

In the standard Porteus Maze test, the user is directed to the next maze until all five mazes are solved (or attempted). The users could not go through the wall and could track back their route within the maze if they chose to. The fact that the timer starts as soon as the maze appeared on the screen was made clear to the users before the beginning of the test.
Although several studies explored this test, the thresholds that helped distinguish safe and risky driving were not reported. Only two studies, to the extent of the author's knowledge, mentioned completion times of the digitised version of all five mazes and their correlations with crash risk [92], [75]. The information that was to be presented to the user in the application, however, was the average completion times of safe drivers to allow the user to judge their scores relative to other safe drivers. Hence crash-risk, which has been correlated with completion time of the five mazes in the two studies, despite indicating a strong predictive capacity of on-road driving, was not an appropriate performance-metric for this application as the author only intended to present relative score-performance in tasks.

Therefore to estimate an average completion time threshold, the digital version of the Porteus Maze test created by the author for *SmartDrive* and was administered to ten people (ages ranged from 23 - 50 yrs.), all cognitively healthy and actively driving. Completion times of all five mazes were recorded for all the ten volunteers (See Table 3.1). The average time taken to complete all five mazes using a tablet with a touch screen was 5.37 seconds. Including the two volunteers who completed the mazes using arrow keys on a laptop, all the completion times were less than 10 seconds. Since all cognitively healthy drivers were able to complete the five mazes in less than 10 seconds even on slower modes of inputs (arrow keys on a keyboard), it was assumed that this can be considered the average. Below average and critically below average threshold times were extrapolated from this testing session as 10, 20 and 30 seconds as shown in in Table 3.2. It seemed appropriate that people taking twice or thrice the average time could be scaled to one and two levels lower respectively. Note these times were used as a proof of concept estimate for exploring the prototype; the author is not claiming they have clinical or on-road validity as this requires testing with a much larger population at a future date.

Table 3.1: Completion times of the mazes recorded for 10 healthy adults with age-ranges, gender and device details

Device	Age range	Gender	Completion time for all five mazes (seconds)
Tablet, touch screen	20-25	M	7.67
	20-25	F	8.32
	20-25	F	4.92
	20-25	F	3.95
	20-25	M	4.32
	20-25	M	3.87
	30-35	F	3.7
	50-55	F	6.2
Average Time	—	—	**5.37**
Laptop, arrow keys	20-25	F	6.7
	20-25	F	7.8

Table 3.2: Score thresholds and performance levels established for the SmartDrive prototype's Porteus's Five Mazes test. Note these are for proof-of-concept only and have not been tested for clinical validity.

Five Mazes Completion Time	**Performance Level**
Less than 10 seconds	Level 1
Between 10 and 20 seconds	Level 2
More than 20 seconds	Level 3

3.2.2 Trail Making Test

The Trail Making test (TMT) is a visual-search and motor-speed task with an element of task-switching that measures attention and is known to quantitatively indicate a person's Executive Function [48], cognitive skills that are integral components in determining driving fitness [10]. It consists of two parts, Part-A and Part-B, both of which have

been used widely in cognitive screening for dementia [14] and in other assessment applications designed to assess safe driving in older adults [3].

Activity Description:

Trail Making Tests involve connecting randomly positioned numbers and letters as fast as possible while following a pre-defined sequence. Part A (TMTa) contains only a number sequence: 1-2-3 so on until 25 (total of 25 points). These numbers are placed in a randomised location, within circles and the person is asked to trace a line between the circled numbers while following the correct order. In a similar fashion, Trail Making Test Part B (TMTb) involves joining the alternating number and letter sequence starting with 1-A-2-B-3-C so on until L-13 for a total of 25 points (See Fig 3.2).

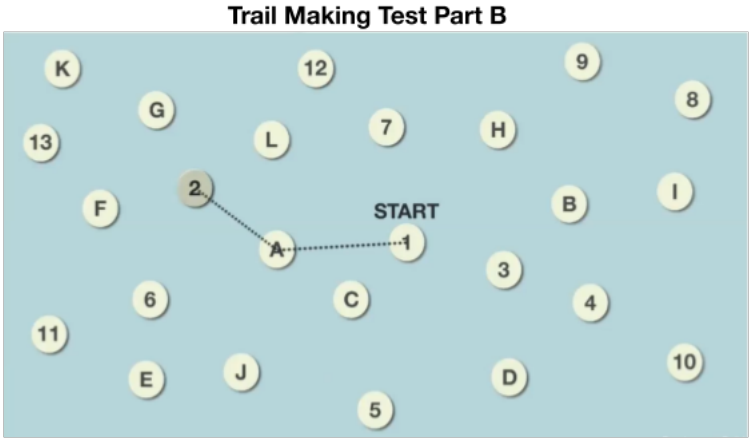

Figure 3.2: Screenshot of the TMTb test created for SmartDrive. The user starts at 1 goes to A and taps on alternating numbers and letters until L-13.

This test is generally administered using paper and pen with a clinician or a medical professional administering the test and timing it [82]. The completion time of both tests individually as well as combined have shown to predict driving errors [26] and have recorded high correlations with crash risk especially in older adults with Alzheimer's disease [28]. Appendix O includes the pictures of both parts of these tests.

Digital Implementation:

Studies have shown significant correlations even with digital versions of this task with on-road driving although the screen sizes differ with the devices used [87]. The Smart-Drive application was designed with the idea of tapping on the buttons with numbers/letters on them. If the right sequence was tapped, a line joining the buttons was automatically drawn. Since this test was designed for self-administration at home without assistance, if the wrong number or letter was selected, the right button was highlighted to help the user progress in the test. The timer started as soon as the user tapped the button: 1 with their finger.
Coupled by the need to reduce the total assessment time and the fact that TMTb has shown higher correlations with on-road driving when compared to TMTa [9] [70], a digital Version of only Part B was implemented in all version of *SmartDrive* using the Unity 2D Game Engine.
Since the clinical validity of the paper and pen TMTb test was established but that of the digitally implemented version designed by the author was not, there was a need to compare scores in both the original form of administration and the application design. To account for the difference in the threshold times of both forms of administration, a total of 16 people were administered this test in both forms and the average difference was used to offset the times recorded in the pen-and-paper version. After randomising in which the mode of test was presented (balanced between pen and paper vs. digital), on average, it was noticed that on average volunteers were able to finish the digital version of TMTb 18 seconds faster than the pen and paper version. This offset was employed in the threshold scores observed in studies that administered pen and paper versions [9] and the threshold scores were adjusted as shown in Table 3.3. Note these times were used as a proof of concept estimate for exploring the prototype; the author is not claiming they have clinical or on-road validity as this requires testing with a much larger population at a future date.

3.2.3 Useful Field of View

This test measures visual fields: both central and peripheral [12]. It includes three subtests: (1) a central visual identification that measures speed of information processing,

Table 3.3: Score thresholds and performance levels for TMTb test

TMTb Completion Time	**Performance Level**
Less than 57 seconds	Level 1
Between 57 and 255 seconds	Level 2
More than 255 seconds	Red Level 3

(2) central and peripheral stimuli identification that measures proficiency in dividing attention between central and peripheral visual fields and (3) peripheral stimulus identification among distracters to measure ability to ignore irrelevant information.
UFoV has the highest significance of correlation with on-road driving performance of all the three tests selected for *SmartDrive* [32]. UFoV has shown high prediction capacity for at-risk drivers living with dementia [84], [86]. For this application, the second subtest was selected as it showed the highest significance in correlation to on-road driving in presence of distracters and hazard perception [12].

Activity Description:

As per established protocol, this test involved identification of two stimulus, the duration of which varied as the test progressed. At the centre, a car or a truck was flashed for a brief period of time (starting at 500 milliseconds), at the same time a car was flashed in the periphery (one of eight possible locations) for the same period of time. The user were asked to note both stimuli and select what they saw in the centre and the periphery (See Fig. 3.3).

If the number of successful trials were three or more out of four for one flash duration, the flash time was reduced by 50 milliseconds, if the accuracy for one flash time was less than three out of four trials, the duration of stimulus was increased by 16.67 milliseconds. This was repeated until a flash time where 75% accuracy was achieved, this final time was noted as the score of the user. Different thresholds for average times have been recorded, the scores that were observed more frequently in literature were incorporated into the design [103], [13], [77].

Figure 3.3: Screenshots of the three steps of the Useful Field of View Sub-divided attention sub-test that was implemented in SmartDrive.

Digital Implementation:

For the purpose of the SmartDrive prototype only the second sub-test of the UFoV was digitally implemented because of its higher correlations to on-road driving, especially perception of hazards and driving performance in the midst of distractors [50]. Along with instructions and a practice session at the start of the task, the algorithm described above was implemented to calibrate the least flash time for which 75% accuracy of stimulus identification was achieved.

Table 3.4: Score thresholds and performance levels for UFoV test

UFoV display time	**Performance Level**
Less than 100 milliseconds	Level 1
Between 100 and 350 milliseconds	Level 2
More than 350 milliseconds	Level 2

3.3 Applying the Persuasive Design Model

The design of the feedback presented to the user was guided by the Persuasive Systems Design (PSD) Model [73]. As shown in Fig. 3.4, the overarching 'Intent', 'Event' and 'Strategy' for a driving self-assessment application were initially recognised. (1) The intent of the application was directly used from our research questions: to promote the

user to explore their driving ability and safe driving decisions, (2) The event included the set of cognitive tests we had chosen and (3) the strategy chosen was a direct message route: useful feedback on user's performance in the tests. The different features that would be effective in persuading the user to accept and use the application were identified through the support options that the model provides. The factors that influenced the selection were suitability to a driving self-assessment application and whether the feature could be implemented given the project's time constraints.
The PSD Model granted several design principles to adhere to depending on the context established. It was essential in discerning relevant features in the context of a driving self-assessment application. The support features (highlighted in bold in Fig. 3.4) were implemented as follows. The Primary task for the user was 'Self-Monitoring' of their driving-related cognition. The design included multiple Sign-ins to allow user to track their scores and observe any trends in their performance over time. The Dialogue support was delivered through the 'Follow-up Suggestions' presented to the user as part of the performance feedback. Although there was not real-time dialogue bot or potential consultation with a real person, the assessment and feedback were real-time and informative to the user. The System Credibility was established through Trust and Verifiability. Study references were provided to the user as part of the 'More Information' screen shown in Fig. 3.6. The application also acknowledged the constraints of single-time testing in the feedback presented to the user to ensure transparency in app-limitations. Finally, Social Comparison of the user's scores with that of the norm values was presented as part of the visual chart in the feedback screen.

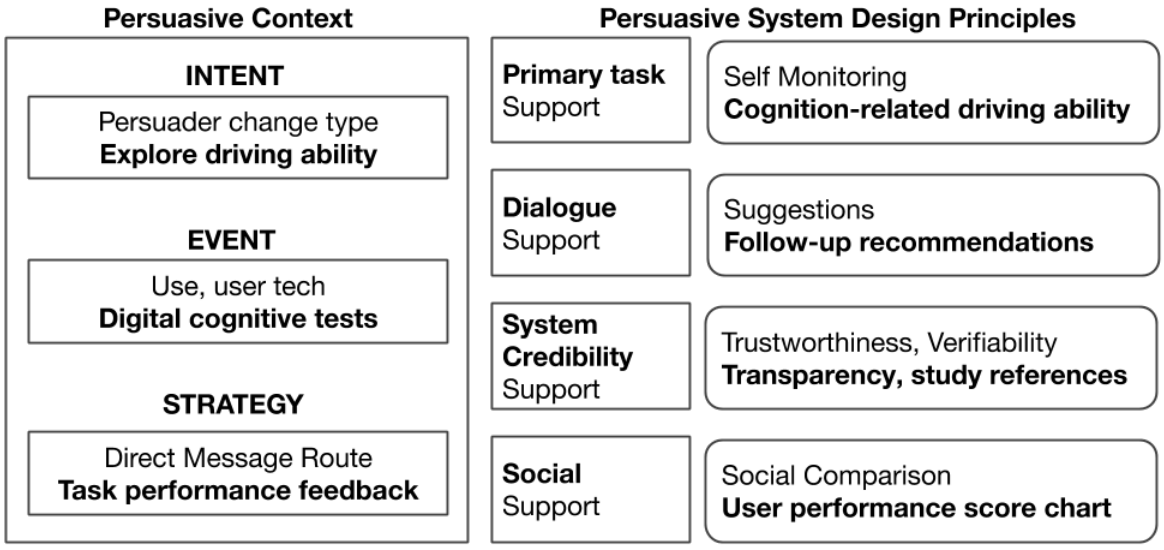

Figure 3.4: Applying Persuasive Systems Design (PSD) Model to a driving self-assessment application. The text in bold refers to the features of the SmartDrive application corresponding to the PSD model's framework.

3.4 Participatory Design

3.4.1 Co-developing with an older adult driver

In addition to the presentations with community partners mentioned previously, throughout the development process the author had monthly discussions about the prototype design with an older adult driver (Age: 83 years, actively driving) who was involved in the project in the capacity of a co-developer, an expert advisor as a potential user. At different stages of design, feedback received from the co-developer was incorporated into the interface to improve its overall usability. Due to the constant involvement of the co-developer in the development stages of the application, they were excluded from the usability testing studies to avoid any biases.

Each of our monthly meetings would begin with a collaborative walk-through of the application thus far designed to identify points of difficulty for potential users in each screen's layout and language. This was followed by discussions on the wire-frame of the prototype to recognise possible improvements that can be made to simplify the navigation and layout. Prior to the meeting, the author would create multiple options to address each of the limitations identified in the earlier meeting and present them to the co-developer for their feedback. After a consensus was reached, appropriate design changes were made and the final run-through was collaboratively analysed. At the end of the meeting, notes listing the final design decisions were made to compare with the guidelines mentioned by usability frameworks found in literature.

Two presentations were initially conducted with our community partners to acquire potential users' opinions early on in the development process. These presentations included interactive workshops at the local senior's group with 20 members of the Bits & Bytes Club, a computer club for mature adults and a total of 10 people (residents and family members) at Schlegel-UW Research Institute for Aging. Four discussions in total were conducted with these groups to understand a potential users' perspectives of such an application and their intent to adopt it. They were distributed over a period of two months to discuss the progress of the application design accordingly. Following the presentation of the research objectives, the discussions and feedback from the members were noted. Those design aspects and opinions that appeared repeatedly were noted and discussed among researchers for possible implementation. The following list details highlighted

points of the participatory discussions:

1. **Wording**: Older adults from the workshops stated they wanted the design to be sensitive towards the tone used. The words "tests" and "results" as well as any words with a connotation of assessment were considered judgemental as opposed to neutral words such as "tasks", "activities" and "summaries". A more user-friendly tone was overall incorporated in the prototype that followed. Since this was a self-assessment with no involvement of clinicians or the ministry of transportation with the objective of using the application due to one's own volition, the wording was crucial to encourage use in the first place and to also make clear that the application was not a replacement for a professional assessment. It was concluded that an authoritative tone would not have appealed to this user-base.

2. **Objectivity**: In general, a tone of objectivity was recommended for the language used in the design and also the presentation style of feedback presented to the user. Having an impartial presentation of the metric or the user's scores in the tasks without incorporating 'good' and 'bad' interpretations from the application was recommended. This was a challenge since there was a fine balance to be sought so as to avoid sugar-coating bad results and dismissing good performance.

3. **Simplicity**: Many older adults insisted on a minimal layout and a visual representation of information; avoiding lengthy paragraphs was stated. Older adults mentioned that text-filled layouts would not garner interest and would additionally prompt them to skip the text, some of which (instructions etc.) would be necessary to proceed.

4. **Connection to Driving**: Many older adults did not feel that cognitive tests would provide an accurate picture of in-car behaviour. The connection was not immediate, which highlighted the need for the app to explain through study references or images of driving aspects with connections to the test scores.

5. **Potential Misuse**: While the idea of the application was to empower the older adult driver with information about their abilities, the possibility of substituting this with visits to their physician was discussed. This was classified as a misuse as

the app is not intended to replace essential medical visits, rather to complement and provide more information.

6. **Actionable feedback**: Several older adults required the application to have a useful 'take-home message'. In addition to self-assessment and objective quantification of their abilities, they wanted to be presented with effective recommendations that would help increase their safety on the road.

3.5 Wire-frame design

A unidirectional flow was used in the application. Fig. 3.5 illustrates the screen-to-screen navigation of the pilot version of SmartDrive, the screens are numbered and are referenced in the wire-frame described below.
After the introductory screen (1-Welcome Screen) which displays the logo and tagline, the user can click on one of three options: (2) Sign In, (3) Play Now and (4) Sign Up (See Fig. 3.6). The first and third options would ask the user to input details regarding their usernames and passwords while the second option proceed to a screen that lists all the tasks that the user can opt to perform (5-List of Tasks). In the pilot version, only TMTb was used as this was an exploratory "proof-of-concept" study. After the user clicked on TMTb, instructions explaining what the task entailed were presented along with buttons labelled 1, A, 2...4, D. The user was asked to tap on the buttons in the right sequence (See Section 3.2, sub-section: Trail Making Test for more details). After completing the practice session, the user was then presented with the actual task (7-Timed Task).

After completion of the timed task, the user was presented an opportunity to pause and consider a plan (8-Pause and Plan). This screen included three consecutive questions: (1) 'What do you expect your result to be?'. (Options: Average, below average and critically below average) followed by (2) 'What might your next steps be after seeing your results?' (Options: text input) and (3) 'Might you be willing to share this information? If yes, with whom?' (Option: text input). These three questions were designed in collaboration with the co-developer to promote the idea of early planning. The idea of a 'driving plan' is mentioned in the screen. The author, co-developer and the co-

researchers define this plan as 'a series of steps that is unique to the situation and ability of the older adult driver that maps the possible progression of their driving career to support them in making safe driving decisions and interventions when needed or even cease driving if necessary'. This screen was designed to promote advance planning for driving cessation, the significance of which was explained in Section 2.1.1.
Following this screen, three summary styles are presented in a randomised order for each participant (balanced for bias), details about each style can be seen in Table 4.1 and Fig. 4.1. After the three screen have been viewed, a prompt to email the overview of the session (i.e., includes the task scores, suggestion and plan drafted by the user) is presented, which the user may or may not choose to click. The user then selects the exit button to quit the application.

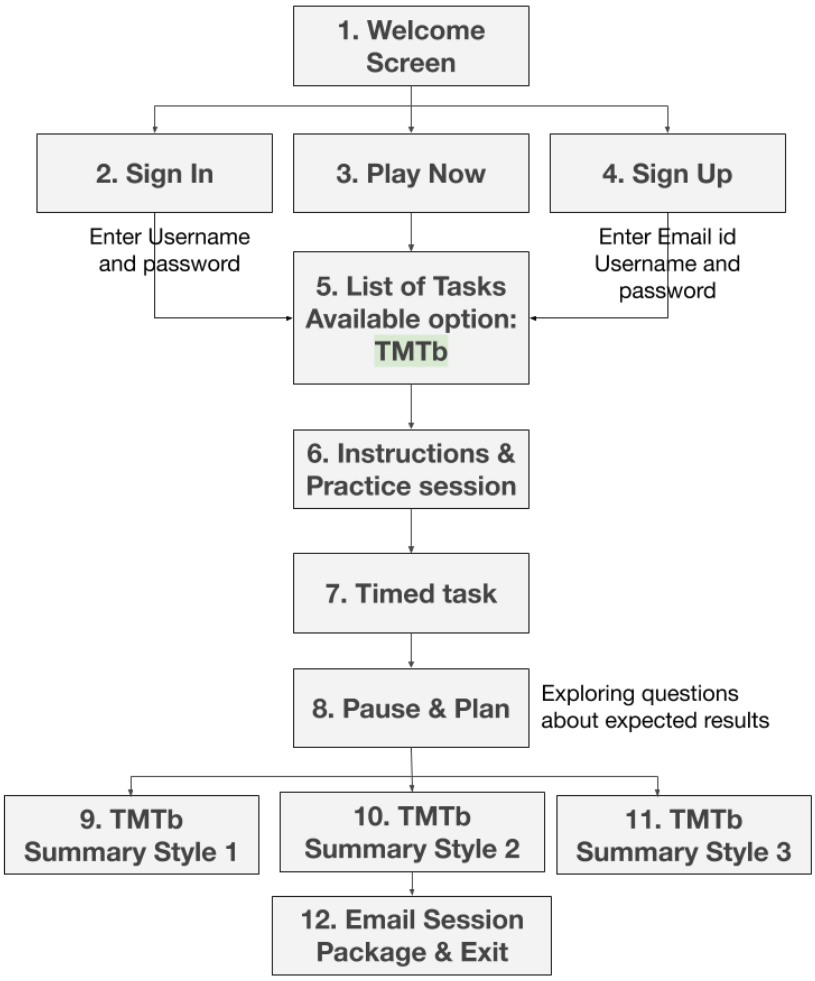

Figure 3.5: Sequence of screens presented to the user in the pilot version of the SmartDrive, numbered in the order of presentation.

3.6 Designing the Interface

Following the PSD model principles described in Section 3.3 and in conjunction with the suggestions from potential users from our community partners, design guidelines from other applications and usability studies were also considered in the development of the interface of the application. The device selected for implementation of the application was a tablet due to the increase in use of this platform among older adults [5] and the observations of general liking towards tablet computers [99], therefore the layout for each screen was designed keeping in mind the average size of a tablet.

- **Colours & Font**: As recommended in the Age-centred Research-Based Design Guidelines [30], identical foreground (Dark blue or black) and background colours (Light blue) were used throughout. A bold and clear, sans-serif font with high contrasting colours (light and dark blues) were selected for the pilot version. Following the Web Content Accessibility Guidelines (WCAG 2.0) guidelines, a level AAA enhanced contrast of more than 7:1 (i.e., 9.8:1) was maintained for any text presented on the screen. For high readability, text was centre-justified throughout and more than 1.5 line spacing was maintained. All the information presented was large in font to ensure clarity of content as suggested by the Universal Design Principles [58].
  The score levels were given green, blue and red background colours (still ensuring background and foreground colour contrast is above WCAG recommended 7:1) to additionally indicate quality of performance. While textual labels were indicative, colours were added as an additional redundant cue.

- **Consistent Layout**: As mentioned in several usability frameworks and studies, the design elements (buttons, primary and secondary information etc.) were uniformly designed in appearance and functionality in all the screens [51]. As was observed in previous usability testing of a mobile healthy application that was designed for older adults to manage medication, there was significant preference to linear navigation (i.e., adoption of a sequential structure of screens similar to that of book, one page after another) [44]. A similar approach was used for this design where the users were given a maximum of two options to either go 'Back' to the

previous screen or to 'Continue' to the next. Multiple options in one screen were seldom presented to the user and appropriate instructions were placed as guidance in these screens. Consistent colours (dark blue) and locations (bottom right) for buttons were chosen to avoid any confusion in functionality and to promote an intuitive flow.

- **Easy Comprehension**: As observed in the usability testing of a fitness web application for older adults [53], instructions are crucial in supporting efficiency of task performance. Detailed and clear instructions for all tests were presented to the user before actual testing. Similar to the paper-pen version of the Trail Making Test, there was a shorter sequence from 1-A to 4-D given to the participants, following the same protocol as part of a dedicated practice session before the actual test was presented in an identical digital format. This was to allow familiarity with the mode of input so novelty of a touch screen and the action of finger-tapping of buttons did not skew the scores. A practice maze and practice session for UFoV were also designed and presented before user proceeded for actual assessment. The layout within a screen was also designed to be generally accessible by left and right hand users, large button sizes were designed to allow for tolerance for error [58].

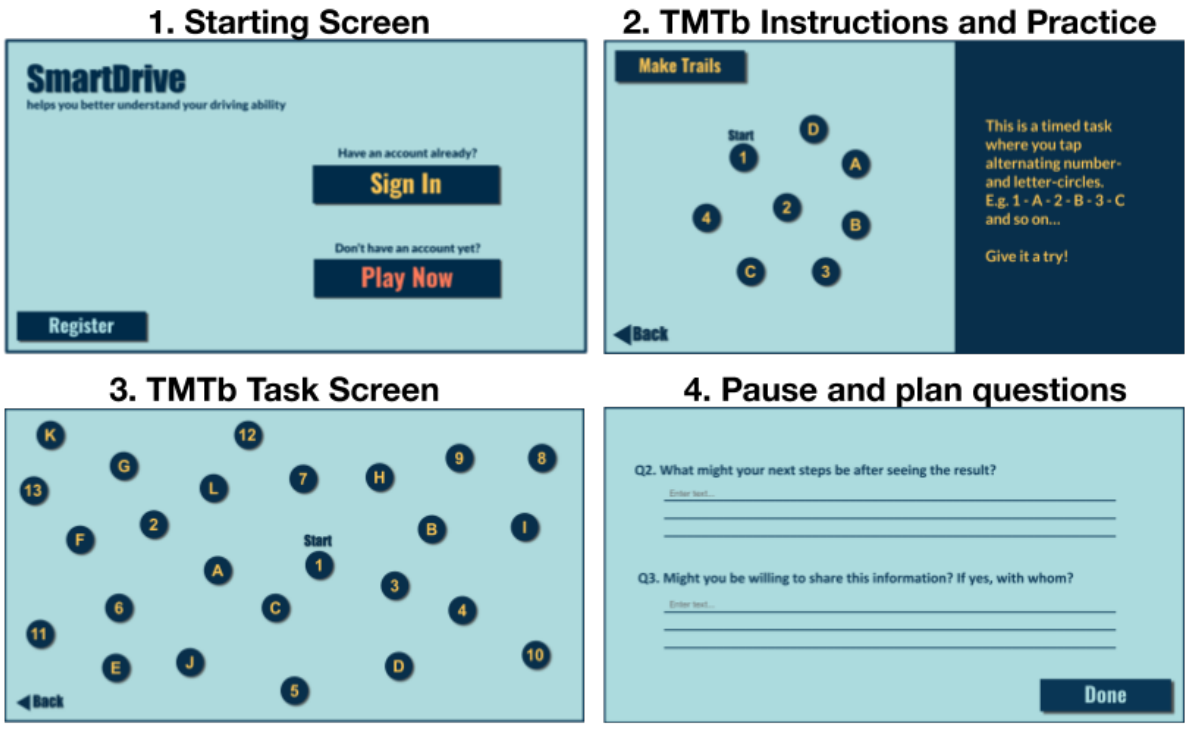

Figure 3.6: Screenshots of the the screens designed and presented to the user in the pilot version of *SmartDrive*: Starting screen, the TMTb task instructions and practice screen, TMTb task screen and Pause and Plan questions.

3.7 Chapter Summary

This chapter details the three cognitive tests (i.e., TMTb, Porteus's five mazes and UFoV) that were selected for implementation in the different *SmartDrive* versions, each of which have shown high correlations to on-road driving. The cognitive skills they measure, the activity involved in each, and its connection to on-road driving have been explained. A short summary is given in the Table 3.5.

Table 3.5: Summary of the three cognitive tests selected for implementation in the *SmartDrive* application along with the cognitive skills they measure and correlation to on-road driving.

Test	**Cognitive Skills**	**Correlation to driving**
Porteus' Five Mazes	Psychological planning and foresight [74]	Completion time of all five mazes has been observed to predict ability to navigate while driving [92], performance in on-road tests (pass/fail) [74] and crash-risk [23].
Trail Making Test, Part B	Executive function [48], attention and task-switching ability	Completion time of the trail has been correlated with on-road driving performance [14],[10] and crash-risk [48].
Useful Field of View	Central and peripheral visual fields, visual attention [50]	The shortest display time for 75% accuracy of stimulus identification has been correlated with on-road driving in the presence of distractors, the ability to perceive hazards on the road [70] and crash-risk [43].

To allow the user to compare their performance with the norm, threshold score values of safe drivers for all the three tasks were sought by administering different modes of the tasks (paper vs. digital) to volunteers and the average scores were noted and implemented in the task summary screens.

The participatory design methods employed involved in the development of *SmartDrive* have been described; the details about the presentations with community partners

and the process of co-development with an older adult driver were detailed. The recommendations received from the participatory methods employed were recorded and addressed in the design of the pilot version of *SmartDrive*. Key UI suggestions from older adults included: (1) Non-threatening and objective wording, (2) Simple language and minimal layout, (3) Explanation to connection of tasks to driving, and (4) Providing the user with actionable feedback. Using these and usability frameworks as guides, a wireframe for the pilot version was created in collaboration with a co-developer (older adult driver). The interface of the pilot version included a starting screen, three different tasks along with their instructions and practice session screens. The author created and implemented three different summary styles in the pilot version of *SmartDrive*, each focusing on a different method of information-presentation (i.e., text, visual map, and driving images) in order to understand the older adults' preference style of presenting their performance feedback.

To the author's knowledge, this is the first time that this collection of driving-related tests has been implemented and evaluated as part of the design of a driving self-assessment application for older adults.

Chapter 4

Piloting a prototype

4.1 Study Objective

The pilot study was designed to explore the initial impressions of *SmartDrive*. In general, this study aimed to evaluate two aspects of the design - Usability and Usefulness - through two guiding questions:

1. How do older adult drivers perceive a driving self-assessment application that is based on cognitive tests?
2. What style of presentation of the performance feedback do older adults prefer?

Both questions were explored by conducting a moderated cognitive walk-through of the prototype and a semi-structured interview discussing the participant's preferences, the procedure followed is described in detail in Section 4.2.4 (Interview Procedure). Different presentation styles of the feedback from the tasks were assessed. The goal was to gather information to support the creation of an appropriate style of feedback presentation in order to encourage users to identify, consider, and plan for safe driving decisions.

4.1.1 Designing three feedback styles

For the application to prove useful to the user, the scores that the user received in the tasks should be comprehensible and presented in a manner that is easy to understand. The feedback based on those scores should also be displayed in a manner that incentivizes them to make safe driving decisions.
To explore which presentation style would be most clear, useful and effective, a pilot study was conducted by digitally implementing the Trail Making Task Part B (TMTb) cognitive task and designing three different feedback styles that each containing a different design element as explained in Table 4.1 and Fig. 4.1 below. Depending on the score received in the task, a recommendation was presented to the user as shown in Table 4.2.

Table 4.1: The three different feedback styles presented to the user to relay the information about their tasks scores and performance. Each style includes a different combination of design aspects that have been specified.

Feedback Style	**Design Aspect (DA) 1**	**DA 2**	**DA 3**
(1) Text-only	Text	Labels	Recommendation
(2) Visual score map	User score, score map	Labels	Recommendation
(3) Text & images	User & average scores	Driving images	Recommendation

Table 4.2: The threshold scores corresponding to the performance label and recommendation presented to the user in the pilot version

TMTb Completion Time	**Performance Label**	**Recommendation**
Less than 57 seconds	Average	Repeat the task in two months
Between 57 and 255 seconds	Below Average	Visit physician for further assessment
More than 255 seconds	Deficient	Visit physician for further assessment

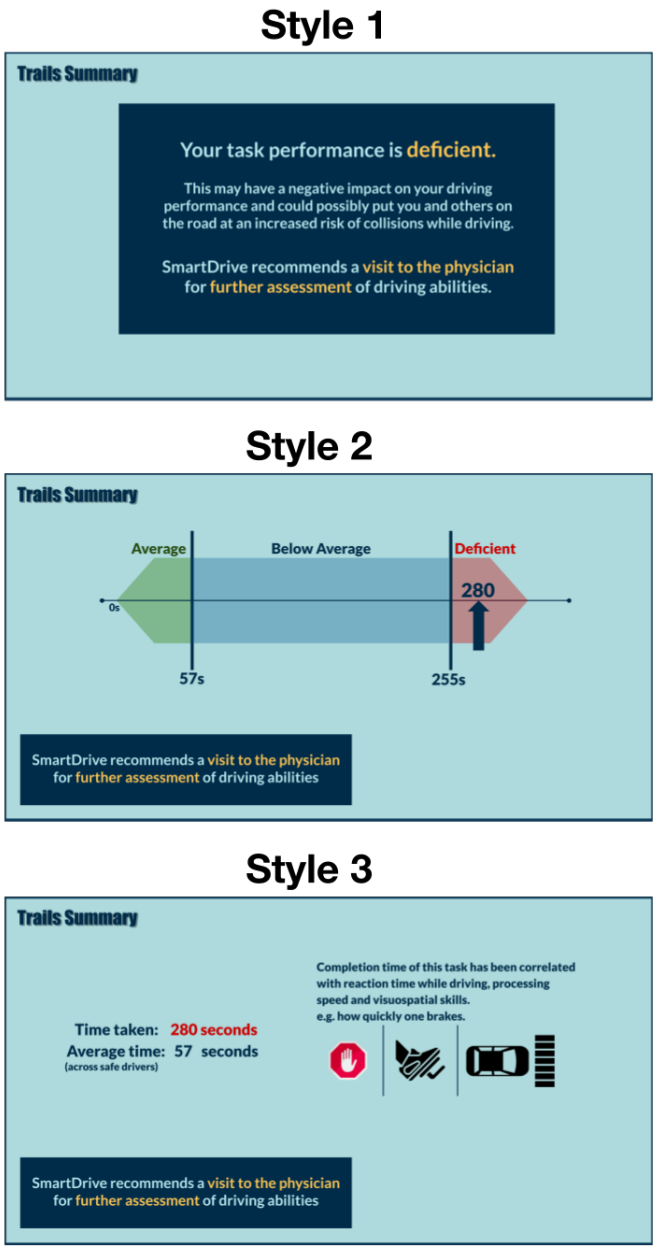

Figure 4.1: Screenshots of the three different feedback styles presented to the user to relay the information about their tasks scores and a recommendation. Each style includes a different combination of design aspect: Style 1: text-based, Style 2: visual score map, Style 3: driving images.

4.2 Study Design

Since this prototype was designed to be used at home without assistance, it was essential to examine if the tasks can be carried out alone. The method of a moderated cognitive walk-through was used, where the user naturally progressed through the screens with the researcher (i.e., the author) answering any questions the participant had as well as asking a set of pre-defined questions about specific design elements. A think-aloud protocol was also used to examine the usability of the application. Popularised in the 1980s [36], the think-aloud protocol has been widely used in several application-evaluations as an effective method in identifying usability problems [98], [79].
As part of the interview, each participant was asked to interact with the pilot version of *SmartDrive* while reading out the content of each screen and verbally expressing their opinions. The researcher would only interject if any aspect of the design or flow was unclear and the participant needed assistance to proceed.
Different presentation styles of performance-feedback were shown to the participants, and their preferences were discussed in an interview that followed.
To understand and compare the differences in performance in the TMTb test on paper versus that using a touch screen tablet, both versions were administered to all the participants. Both, the test order of the TMTb (i.e., paper or digital) and the feedback presentation styles were randomised and balanced amongst the six participants to avoid bias.

4.2.1 Ethics

All procedures obtained clearance from the University of Waterloo Office of Research Ethics (ORE) under the project #41708 titled "Testing effectiveness of different styles of presentation of feedback from performance in a computerised trail making task with senior drivers". During the interviews, the researcher made sure the participant was comfortably seated, a safe environment for sharing opinions was created and the study details in the information sheet were reiterated, specifying the option of withdrawal from the study should the participant wish to do so. An additional disclaimer was made about the prototype regarding having no proven clinical validity before the start to mitigate potential psychological risk or stress caused by the results presented.

4.2.2 Participants

Participants were recruited through the Waterloo Research in Aging Participant Pool. The inclusion criteria were as follows:

- Be 65 years old or older
- Hold a valid Canadian driver's license
- Be actively driving or have stopped driving within the past six months
- Have a minimum of 10 years of driving experience
- Be able to use a tablet, laptop, or similar digital device
- Be able to provide informed consent
- Be able to communicate in English
- Have the full legal capacity to volunteer and are willing and able to follow study instructions

As this was a first stage in prototype development, basic design aspects such as readability, language, flow, etc. were being examined and viability of the application itself was explored. Only cognitively healthy participants (not reporting any type of cognitive impairment in the self-report form, see Appendix K) were recruited for this study to gather early-stage feedback; those living with mild cognitive impairment or dementia were excluded at this stage of research (but were included in later stages, as described in Sections 5.1.1 (Phase-1 participants) and 5.5 (Phase-2 participants).

4.2.3 Interview Questions

Appendix D outlines the semi-structured interview guides used for before the participant interacts with the prototype. Using the two aspects detailed in the framework of the Technology Acceptance Model [27] (Perceived Usefulness and Perceived Ease of Use)

as guides, the interview questions were designed to evaluate the prototype. These questions probe the participant's personal idea of and preferences for such an application, their concerns regarding the current older adult driving assessment and re-licensing procedures. Appendix E outlines the semi-structured interview guide used after the participant interacts with the prototype. The questions asked after the user completed the interaction with the prototype focused on their opinions about the experience as well as the design of the interface, such as font style, colour palette and layout of the screens to their preference of presentation style of performance feedback.

4.2.4 Interview Procedure

After informed consent was obtained, the participants were asked to complete two forms: (i) Demographics and Driving Questionnaire, (ii) Driver's 65 plus self-rating form. The former includes questions created for this research regarding age, driving experience and habits, and the latter comprises a 15-question self-rating driving assessment designed by the AAA Senior Driving (See Appendix J) that allows senior drivers to self-examine driving performance. This was followed by an audio recorded semi-structured interview that discussed their ideas of such an application and concerns about using it. Participants were then asked to interact with the tool and perform the TMTb task while their interactions with the application were screen-captured. Different presentation styles of performance feedback were shown to the participants, and their preferences were discussed in an interview that followed. The test order of the TMTb (i.e., paper or digital) and the feedback presentation styles were randomised and balanced to avoid bias. Participants were also administered a Systems Usability Scale (SUS), a questionnaire designed by John Brooke in 1996 [19] and has been since validated for its reliability and sensitivity to measure perceived usability of a system [39]. As can be seen in Appendix H, it is a list of 13 statements that examine how comfortable and confident the user was while using the application and whether they need assistance of prior knowledge to use it. The participant can select one of five options ranging from 'Strongly Agree' to 'Strongly Disagree'. The overall scores were calculated based on participants' responses to these statements. After the participant completed the questionnaire, they were given a feedback and appreciation letter (See Appendix R) which thanks as well as reminds the participant that *SmartDrive* is a prototype that requires further clinical validation.

Two weeks after completion of the initial app-testing session, participants were asked to complete a follow-up interview on the phone. This was to gauge any changes that were prompted in the participants' driving behaviours as an effect of their experience with the prototype and the information they had received from it. Appendix L lists the interview guide of the short set of questions that were asked to gauge whether there were any impacts of the application use on the participants' driving.

4.3 Results and Discussion

All participants were actively driving with a valid full G driver's licenses. None of the six participants were suggested by their family members to stop driving and reported no discomfort in driving in the night or during busy intersections.

Table 4.3: Demographics of the older adult drivers who participated in the pilot study (n=6).

Participant	**Age (yrs.)**	**Gender**	**Education**	**Driver**	**Experience (yrs.)**
P1	73	Male	High School	Primary	57
P2	76	Female	High School	Primary	50
P3	71	Female	B.Comm	Primary	60
P4	70	Female	High School	Occasional	54
P5	71	Female	B.A.	Occasional	52
P6	76	Male	B.A.	Primary	60
Average	72.43	—	—	—	55.5
Std Dev.	2.44	—	—	—-	3.82

4.3.1 Participant Scores

The TMTb scores obtained by the six participants (paper and digital) along with the SmartDrive Performance level and the AAA Self-rating scale results are presented in Table 4.4.

Table 4.4: TMTb scores received in the pilot version of SmartDrive and AAA Self-rating (n=6).

Participant Code	TMTb time (seconds)		SmartDrive Summary	Self-rating Feedback
	Paper	Digital		
P1	74	42	Average	Go
P2	79	61	Below Average	Caution
P3	73	60	Below Average	Go
P4	51	68	Below Average	Caution
P5	77	43	Average	Go
P6	179	163	Below Average	Caution

As shown in Table 4.5, participants had a mixed reception to the interface; the average usability score was **75.2** out of a possible maximum of 100. While Perceived Usability has been known to influence Perceived Usefulness [27], these ratings did provide a good indication of how easy-to-use the participants perceived the application's interface to be. Through thematic analysis of the interviews (discussed in Section 4.3.2 below), points of improvement in the design that were scored lower were recognised and addressed.

Table 4.5: System Usability Scale ratings for pilot version of SmartDrive (n=6).

Participant	Usability Score (max: 100*)
P1	94
P2	46
P3	52
P4	96
P5	98
P6	65
Average	75.2
Std Dev.	21.6

*A score of 100 indicates strong agreement to all positive statements and strong disagreement to all negative statements about the interface.

4.3.2 Pilot Study: Thematic Analysis

A qualitative thematic analysis was done to analyse the reactions and responses of the participants. Audio recordings of the interviews and cognitive walkthroughs were transcribed verbatim. Preliminary deductive and inductive codes were collectively identified by two researchers (the author and a second researcher) and each transcript was coded following the defined coding scheme. This process was repeated until data saturation. Each code was then discussed by three researchers (led by the author) and categorised into its respective overarching theme and finalised only after the authors reached a consensus. The five themes that emerged at the end of the coding process and their respective sub-themes are summarised in Table 4.6 and described in the following sub-sections.

The order in which these themes are listed follow that of the chronological order of use. To begin with the user's *Awareness* of the need for assessment, driving cessation is recognised, following which the various *Motivations for Use* of this application are identified. This is naturally followed by the availability and *Accessibility* of the technology (device and design) is discussed. After the interaction with the application, the idea of user's perception of *Trustworthiness* of the application is explained. This indicated the next step as to what possible impact the application might have on the user's next steps, namely their *Action Plan*.

The sub-themes that were associated with the overarching theme along with number of participants who mentioned it are listed below. A quote representing for sub-themes has been included to illustrate context.

Table 4.6: List of themes and sub-themes emerged from the thematic analysis of pilot data

Theme	Sub-themes (Frequency, n-max=6)
1. Awareness	Acceptance of ability decline (n = 4) Observation/comment by someone else (n = 2) Wake-up calls (n = 4)
2. Motivations for use	Curiosity (n = 3) Maintaining autonomy (n = 6) Safety (n = 5) Self-improvement (n = 6) Scope for introspection (n = 2)
3. Accessibility	Simple Language (n = 2) Feedback style & colours (n = 6) Availability and familiarity with the device (n = 6)
4. Trustworthiness	Applicability to driving (n = 5) Score explainability (n = 6) Feedback tone (n = 6) Reliability (n = 6) Appropriate suggestions (n = 5)
5. Action plan	Methods to improve driving (n = 6) Seek medical assessment (n = 3) Discuss with family/spouse (n = 5) Change in driving habits (n = 3) Alternative Transportation (n = 3)

4.3.2.1 Awareness

Participants were generally aware of possible cognitive changes that might occur as one ages and how these changes would affect their driving ability. This theme encapsulated the user's state of mind and preconceptions about their abilities. All six participants recognised that adjustments to their driving may be necessary to continue driving safely on the road.

- **Acceptance of ability decline** (n = 4)
  This sub-theme addresses that four people acknowledged and were accepting of possible decline in their cognitive ability and even the potential necessity of driving cessation. This is crucial in influencing the need and intent to use an assessment application.

  P1: *"People are getting older and we are not getting better at driving, you know, let's face it."*

- **Observation/comment by someone else** (n = 2)
  Awareness about the need for driving cessation due to age-related cognitive decline was cited as comments or observations about their driving from the passengers (family, friends or a person from their social circle) or perhaps a physician. Two of the participants expected their family members or friends in their immediate social circles to comment about any errors made during driving and this was mentioned as a helpful step towards understanding the need for driving cessation.

  P3: *"Hopefully your family or spouse...a good friend told that you really shouldn't be driving."*

- **Wake-up calls** (n = 4)
  Personal experience through driving mishaps was stated as a source of this awareness. These mishaps included a range of signs from honks from fellow drivers on the road to frequent feelings of being lost or parking or speeding tickets. Minor accidents such as backing into a pole in a parking lot were also discussed. These mishaps seemed to play the role of warning signs to the participants to self-examine their driving ability.

P5: *"People start honking at you...getting tickets is another clue, starting to get lost, [these] are indicators [that you should question your driving ability]."*

4.3.2.2 Motivations for Use

After **Awareness** of ability decline and possible need for driving cessation was established, reasons for using a driving self-assessment application were identified. They revealed four predominant rationales as to when and why participants would approach such an application. This analysis helped in identifying at what point in an older adult's driving career would a driving self-assessment application be most relevant and useful.

- **Curiosity** (n = 3) Three of the five participants expressed a general desire to learn about their abilities, this was listed as one of the reasons for self-assessment.

  P4: *"It was a fun kind of a thing because it was an opportunity to find out a little bit more about me."*
  P2: *"[to see] if they are still very sharp like: 'yeah, let me see how I am doing'"*

- **Maintaining autonomy** (n = 6) All six participants expressed interest in maintaining the independence and mobility that driving allows.

  P3: *"Fight, for my right [to drive] (laughs). Really consider to study, to change, to learn...to improve [my] results."*

- **Safety** (n = 5) A majority of the participants expressed concern about their ability to drive safely on the road. An app such as SmartDrive seemed relevant to identify issues that need to be solved or improvements that need to be made.

  P5: *"Personally I CANNOT imagine life without a vehicle but by the same token, if I am a threat on the road, is it safe to leave me alone? No, it is NOT."*

- **Self-improvement** (n = 6) All six participants were interested in improving their cognitive skills and driving skills.

  P1: *"As long as they give you the opportunity to correct your mistakes. If they would just sit back and say 'listen you did this and this wrong' and yanked your license...at least give the person a chance to correct their mistakes."*

4.3.2.3 Accessibility

After the *Motivations for use* of the application were recognised, the discussion about its accessibility ensued. This overarching theme encapsulated the significance of the general accessibility of first, the device (i.e., the tablet) and secondly, the availability of time to use it. The design itself and how accessible the information on it was: the style of feedback and the language used throughout the application, were also listed as factors that influenced the participant's intent to use the application.

- **Simple language** (n = 2) Two of the six participants mentioned that the language used in the application should be simple and easy to comprehend. While the descriptions in the application were mostly in layman terms, some technical terms were used to ensure authentic replication of meaning.

  P5: *"[something that is] easy to understand, written in a language that...people speak, not a whole lot of lawyer's or doctor's terms. We are all retired people, right? So something that's gentle to read but at the same time delivers the message it needs to deliver."*

- **Feedback style** (n = 6) A key aspect of this study was to explore the effects of different styles of presentation of feedback. This sub-theme reflects the views of the participants and their opinions on the different styles designed. Five of the six participants preferred a combination of the text-based layout (Fig 4.1 Style 1) and the graphical layout where their score was mapped relative to the average driver (Fig 4.1 Style 2). This design was pursued in the later version. Others mentioned several preferences pertaining to the need for numeric information of their relative performance, colours used for the visual map and so on were recorded. Some of these were taken into consideration for the next version but there was a limitation in the flexibility of options due to time constraints. Possible expansion of customisable features for the final product are discussed further in Section 7.3: Future Work.

  P2: *"The graph talked to me...[informed] 'you are a little over', might be a good idea to talk to a physician."*

P1: *"A bar should be a must-have. Text, I mean you know you miss that, often times you don't read the text. I know I'm bad for that but a bar is hard to miss."*

- **Availability of and familiarity with the device** (n = 6) All six participants mentioned this sub-theme as one of the major barriers in using the application. Without the access to the device itself on which the application is deployed on (tablet for this version) and the familiarity with the operation of it, this application would not be deemed accessible or usable. All six participants mentioned that they would be willing to spend at least ten minutes every month or two on the application for an assessment session.

P2: *"I'd like to think I'm computer-literate. I have and work on a computer several hours a day and everything and I enjoy it but a lot of people don't like it and are scared."*

4.3.2.4 Trustworthiness

Following the interaction with the application, the question of credibility and reliability was recorded. The sub-themes covered in this overarching theme was observed to influence the intent to pursue any of the suggestions presented by the application.

- **Applicability to driving** (n = 5) Four of the six participants noted a correlation of the task with on-road driving. Two participants expressed a strong belief in correlation of the tests to driving while two mentioned a reasonable connection and the need for expanding the number of tasks to add reliability. One participant did not believe there was any correlation with on-road driving; the other participant was unclear about their final opinion about driving but did not at any point dismiss the legitimacy of a correlation between the test and driving completely. Although cognitive-testing was seen as a viable method of driving assessment in general, three participants mentioned the effectiveness of simulating realistic driving scenarios on a tablet to demonstrate more significant correlations with on-road driving.

P6: *"I don't think that relates to actual driving, if somebody was...if the light turned green or red, uh I don't think I would go through that red light, I don't think that correlates to doing that task."*

P5: *"Because in a way, it [cognitive testing] is the same kind of thing, as long as you have a complex situation, or somebody has to make a decision. You'll get, I would think, valuable information."*

- **Score explainability** (n = 6) All six participants mentioned the need for explanation of why they received the score that they did. Since this was not the intent of the design of the test, the explanations for the scores of the participants could not be inferred. However, three participants noted that identifying why they scored as they did was essential in understanding their ability and their trust in the application.

  P3: *"After seeing the results, first I have to figure out why I am doing poorly...I didn't see very fast, I couldn't find the things I needed, I spoke them but I couldn't find them. Is it lack of attention or is it because I'm really slow or is it confusion?"*

- **Feedback Tone** (n = 6) This sub-theme identified the need to deliver results in a way that isn't critical or threatening, but more factual and respectful to the user. The tone was identified crucial in influencing the participant's perception of credibility. The tendency to dismiss a high-handed or a judgemental tone was mentioned by all six participants. Two participants also mentioned the need to 'be blunt' when needed to avoid misunderstanding. This becomes a challenging balance of being clear and accurate without being aggressive or disrespectful.

  P2: *"You have to be very delicate. It shouldn't sound like criticism but you are concerned [about user's driving]."*

  P4: *"You know, it's got to give people feedback that's not so negative that they're going to feel like throwing it against the wall. But at the same time that it's an encouraging feedback of things that...that a responsible person would want to follow through on, you know."*

  P4: *"I would hope that it [application] could just bluntly come right out and say you really need to reconsider your driving doing and talk with a doctor. People need to*

be told, you know? Like in this point in time I think my cognitive abilities are fine. If they were not I certainly hope somebody would tell me so."

- **Reliability** (n = 6) This sub-theme allowed us to identify the limitations of the application. The idea of single-time testing was questioned, its accuracy and reliability were discussed. All participants mentioned various factors that would affect their perception of credibility or reliability, some directed towards the protocols used in the administering the task.
  Two participants explained their view of 'having a bad day' and how the mood and alertness would vary on different days and even different times in a day, the need to capture and account for such variability was discussed.
  Two participants mentioned the effect that familiarity with touch screens and tablets would have on their performance, which is much less of a concern in paper and pencil tests as people are generally much more comfortable with that format. This is a valid concern that cannot be escaped for online applications. Latency in connectivity and other factors would affect the final scores and transparency about these factors became a goal for the subsequent SmartDrive design.

  P4: *"I think it's more a matter that I am not a computer person...I've been playing with pen and paper and I'm a dinosaur...I have been dragged screaming into this new decade and I continue with my old decade."*

  P1: *"So one test one time doesn't really indicate that you are good or bad it just indicates that you are not familiar with the program...to me anyways."*

- **Appropriate Suggestions** (n = 5) Although two participants found the suggestions to be relevant, this version of the prototype only presented two options that were dependent on the task completion time of the user as shown in the Table 4.2: 1. Repeat the tasks, 2. Visit a physician for further assessment. This line of inquiry helped us recognise the ways to improve and expand on these two suggestions. Participants were not only interested in improving their current skills (Subtheme: Seeking Improvement), they also wanted suggestions that were more appropriate to their driving skills and situation. They were interested in understanding what the gradations of times meant. This was addressed in the subsequent version

by designing a general list of possible options that the user can pursue and is explained in detail in the Section 4.5, Table 4.11.

P4: *"No I think it [feedback] would have to be more than that... [application should] give people something to think about, to consider the next time they get into a car...like [if] it said 'you're doing alright but you need to be more aware of your surroundings'."*

P2: *"Yeah...[the application must] have a cut off at 57 to 75 (seconds, TMTb completion time)...[should suggest] 'have a look at the driving book'."*

4.3.2.5 Action Plan

The *Action Plan* that the user implements after their experience with the application naturally followed only if trust in the application was established. Participants discussed potential follow-up options that they would consider depending on the scores they received. This theme allowed us to recognise the limitations of having only two recommendations in our prototype and helped us explore different actions that participants were willing to consider and implement.

- **Methods to improve driving** (n = 6) All six participants mentioned that they would like to be presented with possible methods to improve their driving skills. This was not considered during the design of the prototype as only the aspect of assessment, repeating the assessment, or visiting a medical professional for further assessment were considered. This improvement was also mentioned in terms of general cognitive abilities and this was addressed in the subsequent version's suggestion list.

  P4: *"To me...we need to be told more than we're doing okay, we need to be told what we need to do better."*

  P6: *"...but if I could beat the test, it must mean that somewhere along the line, I'm not as confused as I thought I was, that somehow I'm processing"*

- **Discuss with spouse** (n = 5) When they were asked if they would share their results or discuss the application or their driving with anyone, five participants

positively said they would discuss with their spouse or family. There was some reluctance personal or projected in sharing the results if the scores were lower, but 'spouse' was a consistent answer throughout. Although this might not necessarily lead to safe driving decisions, constructive conversations might prompt good decisions which is one of the prime objectives of this application.
Another reaction to the idea of sharing was to act on results without discussion. Although this wasn't a popular view, it lends to the notion of how driving affects self-image.

P6: *"Well...my wife...and I don't know if I would tell anyone else, but if it was consistently bad, doctor probably, you wouldn't go to friends or anything, or family, it'd be doctor first."*

P4: *"He [friend] would probably respond to what the results are telling him, in a positive way, but he wouldn't want anyone to know why he's not driving anymore."*

- **Seek medical assessment** (n = 3) Three of the six participants wished to seek further assessment of their driving and cognition from a medical professional as a 'next-step' to completing the application task. This was addressed in the current version of the prototype but this allowed us to recognise the need to elaborate on this suggestion further.

  P4: *"And a lot of people...likely younger people, or people who are more computer savvy than I am. And in that big section there might be more people like me, who are not really... so badly below average, but they don't understand computers as well, you know? So go see the doctor and find out what the answer really is."*

- **Change in driving habits** (n = 3) Half the participants mentioned their intent to increase alertness in car while driving, and other changes they would make to their driving habits.

  P4: *"Drive a little more slowly, pay a whole lot more attention, pause you know? Everybody's always in hurry, I said it myself, maybe it is time for me not to be in*

such a big hurry. And there are so many things out there that you have to watch out for. Maybe I should just watch out a little more."

P2: *"The only thing I could do is be more observant. I have no trouble, but when he [husband] and I are talking, my full attention isn't on the driving and he says 'Oh, I've gone past the corner.' and yet I don't go past the corner when I'm driving on my own so I think cut out all the small talk or minimise the diversions."*

- **Alternative transportation** (n = 3) Three of the six participants mentioned public transport or asking family or friends for help as alternative transportation. This was stated as a possible plan for the future if they felt that they were not comfortable driving. They suggested that this option can be explained as part of the list of suggestions presented by the application.

P3: *"Mainly offer alternatives you know, offer ways to bus free, ION or whatever pass, reduced taxi rates, various things like that."*

P6: *"Then [deficient scores] maybe it's time to give the keys to my wife."*

4.4 Analysis of the Pilot Study Follow-up Interviews

Among the six participants who used the application for the pilot study, five agreed to a follow-up interview exactly two weeks after the app-testing session. The sixth participant did not respond to calls and therefore could not be included. Follow-up interview participants were asked about their impression of their application experience from two weeks prior and if it had an impact on their driving habits. These can be seen in Table 4.7. While none of the participants chose to create an early driving plan (See Section 3.5 for definition), three of the five participants mentioned that they'd thought about the scores and the application experience. Four mentioned discussing it with their spouse although the discussion was mostly focused more on the application and the study than their driving. Four of the five participants mentioned that the application caused them to be more aware and alert in the car while driving. No other application effects were cited. Three participants said they would be willing to use the application again and the purpose was to observe any changes in scores.

Table 4.7: Follow-up action plans and number of participants who did or did not consider them in the two weeks after the pilot study.

Action Plans	**Positive reactions** (n-max: 5)	**Negative reactions** (n-max: 5)
Discussion about application or driving	4	1
Explore a driving plan	0	5
Self-introspection about their driving	3	2
Impact of app on driving	4	1
Willing to repeat app-use	3	2

4.5 Design Modifications

Based on the themes and sub-themes identified in the pilot study described above, several possible design modifications to the application were designed. After multiple discussions with the co-developer, modifications addressing the previous themes and sub-themes were selected and implemented. The tables below (See Tables 4.8, 4.9, 4.10, 4.11) list each of the design changes and the related sub-theme along with the guidelines used during the development of the newer version of the application. Section 4.5.1 describes the navigation between the different screens of *SmartDrive 1.0*.

4.5.1 *SmartDrive 1.0*: Wireframe

As seen in Fig. 4.2, after the introductory screen (1-Welcome Screen), which now has additional information about cognitive testing and its administration by transportation authorities and clinicians, the user is presented with the option to view the references for studies that have explored and confirmed correlations of the tasks to on-road driving performance (2-More Information) (See Fig. 4.3). Following this, three options as seen earlier in the pilot version (See Fig. 3.5) are presented to the user (3-Sign In), (4-Play Now) and (5-Sign Up). All three screens lead to a screen listing the three tasks that can be performed (6-List of Tasks). This screen has additional explanations about the metric that is being measured (e.g., completion time for Mazes and TMTb and display time for

UFoV) along with their effects on driving. All three tasks can be performed sequentially (7-7a, 8-8a, 9-9a). After completion of all three tasks, a (10-Pause and plan (Expected scores)) screen appears. This screen contains only two questions, one asks the user what they expect their score to be (three performance label options are provided: Average, Below average and Critically below average). The user is then asked to consider what their next-steps might be if they receive scores lower than expected, there is an text input field to jot down their thoughts.
A combined screen (11-All 3 tasks summaries & suggestions) including the overview of user's performance in all three tasks as well as a list of suggestions on the right are presented (See Fig. 4.4). The user also has the option to view detailed summaries (including user scores, threshold scores, etc...) for all tasks (12-All 3 tasks...). The user then proceeds to the list of suggestions (13-SmartDrive's Recommendations List) that are presented sequentially (See Table 4.9 for details of the list), which the user can choose to read. Finally another screen (14-Pause and Plan (After scores)) asking them to reconsider their next-steps having viewed their scores is presented to the user. They can type any new ideas or plans they might have in the text boxes provided. The last screen (15-Email Session Package & Exit) provides the option to choose to email the session package to themselves from or the user can choose to exit the application.

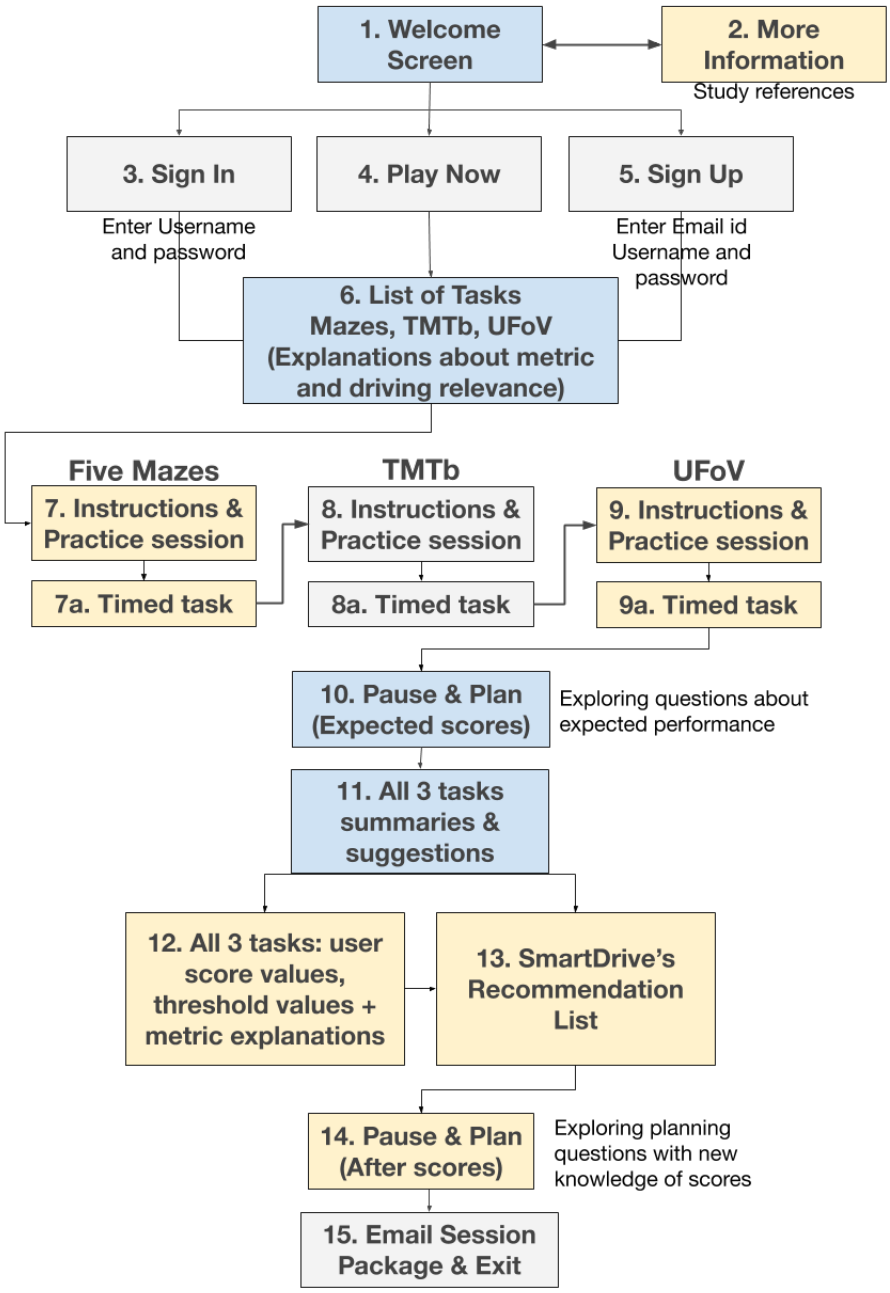

Figure 4.2: Sequence of the screens presented to the user in the *SmartDrive 1.0* version. Screens highlighted in blue have a modified layout while those highlighted in yellow are new additions that were absent in the pilot version.

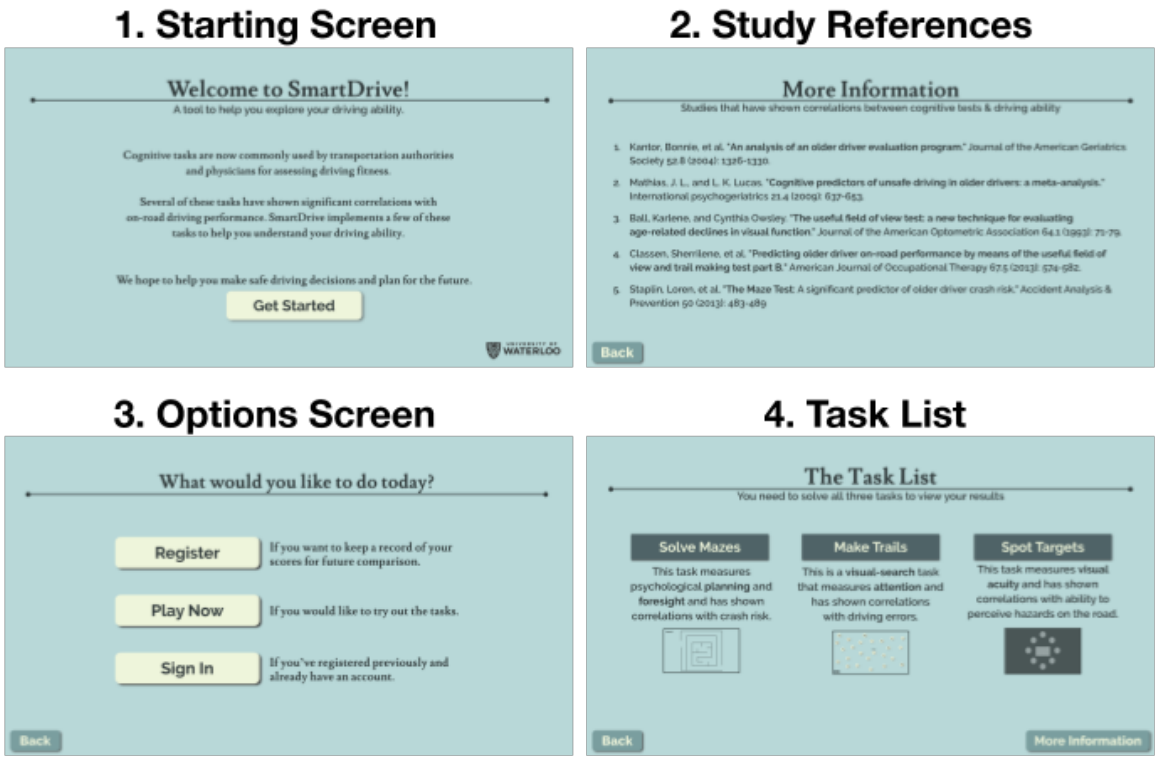

Figure 4.3: Screenshots of the first few screens of *SmartDrive 1.0*: Starting, References, Options and List of Tasks Screens).

Theme: Accessibility

Three sub-themes that emerged under this overarching theme were (1) Simple Language, (2) Feedback Style and (3) Availability and Familiarity of the device (see Table 4.6). Although the application was still deployed on a tablet platform as was earlier, the two other sub-themes (1 & 2) were addressed as shown in Table 4.8

Table 4.8: Design changes made in *SmartDrive 1.0* version to address the *Accessibility* theme.

Sub-theme	**Design Edit**	**Rationale**
Simple Language	Simplifying phrases, explanations and instructions	To enhance the readability of the content, all information presented was edited and the wording simplified where appropriate in collaboration with the co-developer. A few examples of this are: the test 'Useful Field of View' was renamed 'Spot targets' etc.
Feedback Style	Presentation of results	Since the majority of the participants selected a combination of text and visual chart style, this was incorporated in the feedback screen. The preferred performance associated colours were retained and score numbers and additional information was added to the visual chart. The final layout was collaboratively concluded by the author and co-developer after multiple design refinements.

Theme: Trustworthiness

As shown in Table 4.9, several aspects of the theme *Trustworthiness* were addressed and improved upon in the *SmartDrive 1.0* version.

Table 4.9: Design changes made in the *SmartDrive 1.0* addressing the theme of *Trustworthiness*.

Sub-theme	**Design Edit**	**Rationale**
Applicability to driving	Addition of two driving related tasks	The two tests that were previously selected were implemented in *SmartDrive 1.0* to increase the significance of application's relevance to driving and expand the domains of cognitive screening for different aspects of driving abilities.
	Addition of an introduction screen	Explanation and references to studies that have shown test correlations to on-road driving were added in the beginning of the application to provide context and literature references to the user before they begin interacting with the application. This was earlier identified as the Credibility Support System in the PSD Model (See Fig. 3.4) and implemented in *SmartDrive 1.0*

Table 4.10: Design changes made in the *SmartDrive 1.0* addressing the theme identified in pilot analysis: *Trustworthiness* continued.

Sub-theme	**Design Edit**	**Rationale**
Score explainability	Explanation of test metrics	The metrics (completion time, accuracy) used to assess the test performance were explicitly mentioned to increase the understanding of scores and transparency. The phrasing was discussed with the co-developer to ensure readability.
Feedback Tone	Re-wording of performance label	Since a few participants did not like the label 'Deficient' this was modified to 'Critically below average'; the colours green, yellow, and red were retained because of their 'go', 'caution', 'stop' traffic conventions to help quickly identify the user's performance and safety level. This was done while maintaining a WCAG recommended contrast ratio of 7:1 and higher. Different options for the performance labels were discussed with the co-developer to ensure sensitivity and objectivity in tone as was discovered important during the presentations with the community partners (See Section 3.4).
Reliability	Adding a second attempt for TMTb	Limitations of single-time testing were mitigated by allowing a second trial for the TMTb task and the best of both trials would be considered for final scoring. This was to account for first-time unfamiliarity of the digital task and allow a second chance to build strategy and perform better. This was a feature that attempted to address trust and accuracy trade-off. The development team hypothesised that allowing a second trial would help the user build trust that the app will not consider a score where they were distracted or unprepared as well. This was a purely exploratory feature that was examined. The second trial scores also make for an additional data point (TMTb1 - TMTb2 times) that could be compared with the norm (e.g., average age and sex-matched score) once the app is validated with a larger population.

Theme: Trustworthiness

Several aspects of this theme were addressed and improved upon in the newer version:

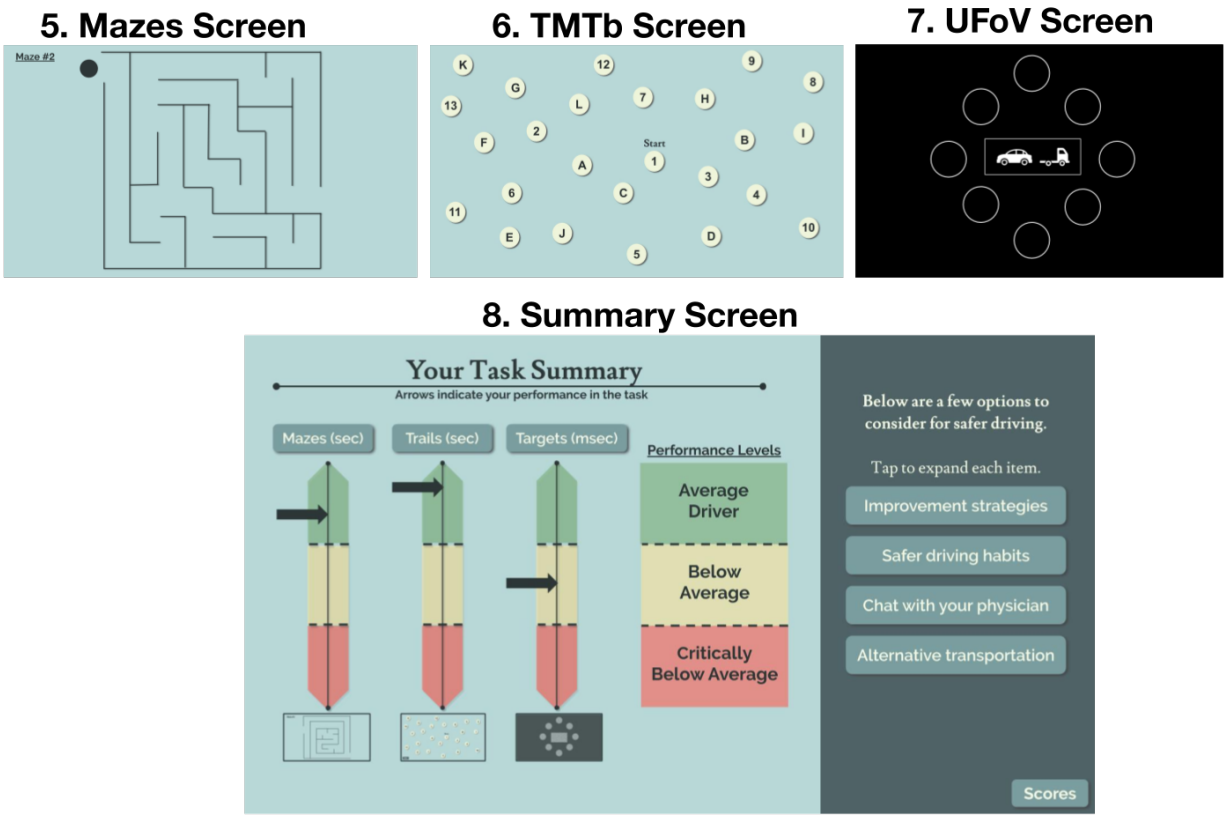

Figure 4.4: Screenshots of the task and summary screens presented in *SmartDrive 1.0* version of the application

Table 4.11: Design changes made in the *SmartDrive 1.0* addressing the theme identified in the pilot analysis: *Action Plan*

Sub-theme	**Design Edit**	**Rationale**
Action Plan	Prompt for early planning after Summary Page	Introspective planning questions were added to the layout after the user viewed SmartDrive suggestions to encourage exploring a plan for themselves The user would have a better understanding of a driving plan after having looked at potential options and should be allowed to think about their own plan once they've looked at their scores.
	Increase Number of Suggestions	Combined with the feedback received about potential next-steps that participants would consider in the pilot study (See theme *Action Plan* in Section 4.6: Pilot Study Themes) and suggestions listed in driving and dementia tool kits [21], [20], driving course, brain training exercises, avoiding busy intersections etc. were added. A general list of suggestions was presented at the end. This was designed in order to respect the user's choice and allow them to identify the suitable action plan for their scores as they deemed fit. Suggestions included a statement regarding limitations of the application assessment protocols (i.e., that it was not a substitute for a clinical assessment) and the need for clarification through a visit to their physician.

4.6 Chapter Summary

This chapter introduced the protocols used for evaluating the pilot version of *SmartDrive*. The objective of the study was to explore older adults' perceptions of a driving self-assessment application and to evaluate the three feedback summary styles that were created. Six participants (average age: 72.4 years, all actively driving and cognitively healthy) were interviewed as part of the pilot study. The data from the cognitive walkthroughs and semi-structured interviews were thematically analysed by three researchers (led by author). The analysis revealed five overarching themes: (1) Awareness, (2) Motivations for use, (3) Accessibility, (4) Trustworthiness, and (5) Action plan. The responses collected from the follow-up interviews were recorded. Four participants mentioned that the app had a positive impact on their perceptions of driving. These included introspection and discussions (with their family) about their driving, increased alertness in the car and their intent to use the app again to critically evaluate their driving and observe changes in skills over time. The sub-themes identified under each theme guided the design modifications made to the pilot version. The design features and the altered wireframe of the subsequent version (i.e., *SmartDrive 1.0*) are introduced along with screenshots. The changes that correspond to the more prevalent sub-theme that they intended to address are listed below:

- Theme: Accessibility, sub-theme: Feedback style.
  Design change: Combination of the summary styles (text and visual map) that were preferred by a majority of the older adults (four of six) in the pilot study were designed.

- Theme: Trustworthiness, sub-theme: Applicability to Driving.
  Design change: Addition of two driving related tasks (Mazes and UFoV)

- Theme: Trustworthiness, sub-theme: Score-explainability.
  Design change: Explanation of test metrics along with references to relevant studies to help establish context.

Chapter 5

Testing SmartDrive versions 1.0 & 2.0

The evaluation of the *SmartDrive* prototype was accomplished through two consecutive testing phases (See Fig. 5.1).
Phase-1 involved an online 20-minute cognitive walk-through of *SmartDrive 1.0* followed by a semi-structured interview. Follow up phone interviews were conducted two weeks after the app-testing session to gauge any effects the application had on the participant's driving. Data from Phase-1 was thematically analysed to identify improvements that could be made in the next version. Limited by the time-frame, a few design alterations based on participant's feedback from Phase-1 were implemented and evaluated in Phase-2.
Phase-2 interviews were conducted using the same protocols as Phase-1. The objectives for this phase were two fold: 1) to evaluate the changes made in the design through the feedback from those participants who were called back from Phase-1 and new participants, and 2) to explore the perceptions of older adult drivers living with dementia.

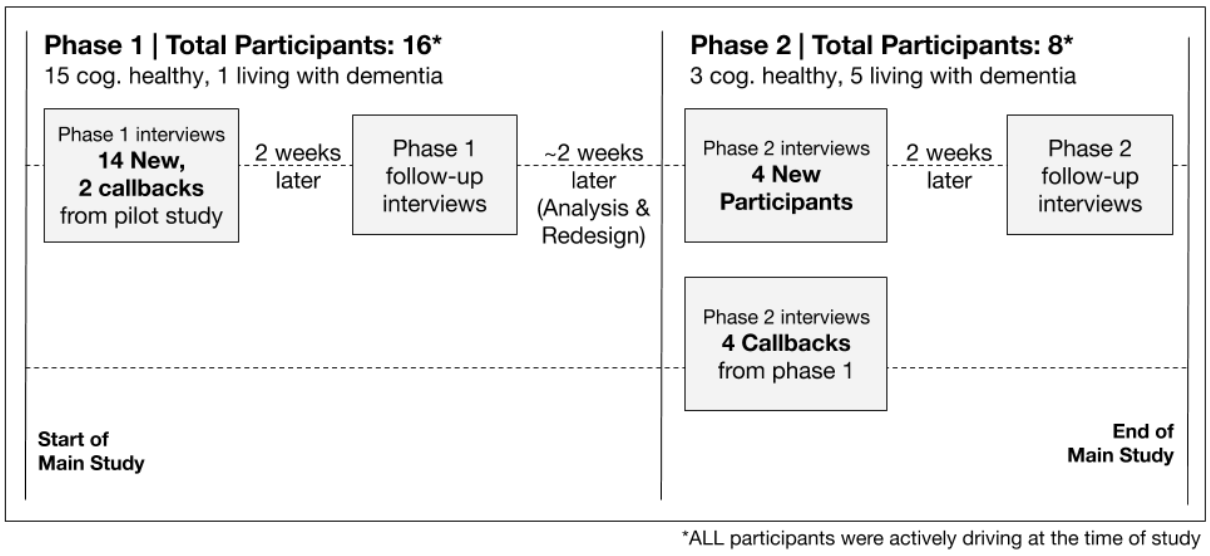

Figure 5.1: Flow of the Main Study describing the timeline of the two phases

All procedures obtained clearance from the University of Waterloo Office of Research Ethics (ORE) under the project #40677 titled "Prototype testing of a digital interface that enables older adults to self-assess their driving ability". Interviews for both phases were online using Zoom because of the COVID-19 pandemic. After the participant, student researcher (i.e., the author) and note-taker (i.e., research assistant) joined the meeting, the meeting was locked. During the interviews, the researcher made sure the participant was comfortable with screen-share and other features of the Zoom environment as well as their tablet. A safe environment for sharing opinions was created and the study details in the information sheet were reiterated, specifying the option of withdrawal from the study should the participant wish to do so. An additional disclaimer was made about the prototype regarding its lack of clinical validity before the start to prevent any potential psychological risk or stress caused by the results presented.

5.1 Study Design

Due to the COVID-19 pandemic and the lock-down restrictions, the *SmartDrive* application and the study were both moved online. Links were used to access the SmartDrive application and the online surveys. Screen-share and recording features of Zoom video chatting software were used. After participants' verbal consent was audio-recorded, a demographics and driving habits questionnaire identical to the previous study was administered online using the Qualtrics Survey Software (a copy of these can be seen in Appendix I). Participants were requested to self-report whether or not they had received a diagnosis of dementia. The evaluation of *SmartDrive 1.0* began with the participants performing the three tasks and receiving their performance feedback. The think-aloud protocol was implemented during the moderated cognitive walk-through, their reactions to each screen and the three tasks were recorded and the author (in the capacity of the primary interviewer) intervened in the process only when the participants found something confusing or if they were unclear on how to proceed. A note-taker was also present during the interview to observe the contexts of the comments made by the participants. The study notes created by the note-taker during the interview were used in conjunction with the interview transcripts to thematically analyse the participant's reactions to the application.

Two weeks post the application testing session, a follow-up interview was conducted over the phone to identify any effects the application might have had on the participants' driving habits.

5.1.1 Phase-1: Participants

16 participants were recruited for Phase-1. This is a higher number of participants than what is typical of research-based prototype evaluation studies. The goal of a larger cohort was to reduce possible misrepresentations that occur due to smaller samples, as can sometimes be observed in other usability studies [37]. All participants except one were recruited through the Waterloo Research in Aging Participant Pool. Two participants were invited back from the pilot interviews to specifically record their opinions on the changes that were made in *SmartDrive 1.0*. One participant who is actively driving with dementia was recruited through the Memory Boosters Club at Waterloo. The inclusion criteria for the main study were similar to the pilot study with a few additions. Since the interviews were remote and on an application that the participant needed to own or have access to, this condition* was added to the previous list.

- Be 65 years old or older
- Hold or have held a valid driver's license
- Be actively driving or have stopped driving within the past six months.
- Have a minimum of 10 years of driving experience
- Be able to provide informed consent
- Be able to communicate fluently in English
- Should own and be able to use a tablet with a functional touch screen.

Interview Procedure

A similar approach to the pilot study was taken to guide the questions for the interview (See Appendix F for interview guide). Unlike the pilot, the questions were more focused towards the design of *SmartDrive 1.0*. Using the TAM (Technology Acceptance Model) as a guide, Perceived Usefulness and Perceived Ease of Use of the application were evaluated as done previously (See Section 4.3.2). After the participant's verbal consent was audio-recorded, they were asked to complete two online questionnaires:(i) Demographics and Driving Questionnaire, (ii) Drivers 65 plus self-rating form. Both the questionnaires were identical to the ones used in the pilot study and can be found in Appendix B. Participants were then asked to interact with the tool and perform the three tasks, Mazes, TMTb, and UFoV. Interactions with the application were screen-captured through recording of the screen share through Zoom. No facial features were recorded since the participants were requested to switch their video off throughout the interview. Their preferences for the performance presentation style were recorded. Participants were then asked to fill out three surveys each measuring Perceived Usefulness Appendix B, Usability and Design of the application as perceived by the participant. After the participant completed the questionnaire, they were given a feedback and appreciation letter (See Appendix R) which thanks as well as reminds the participant that *SmartDrive* is a prototype that requires further clinical validation.

Interview Questions

Appendix F outlines the semi-structured interview guide used after the participant interacted with the prototype. Unlike the pilot stud interview guide (Appendix D and Appendix E), the questions were focused towards the application and the design itself rather than the user's opinions on re-licensing policies etc. This change was made since this study was not exploratory as the pilot study was intended to be. The questions in the interview delved into the each of the three tasks, opinions on the layout, and other design aspects.

5.2 Phase-1: Data Analysis

Cognitive walkthroughs and the interviews of all 16 participants were transcribed verbatim by our research team. Three researchers (including and lead by the author) individually coded two transcripts each and identified the codes that emerged. Approximately a hundred codes were gathered, discussed and edited to establish context. Similar codes were grouped and those irrelevant to the research questions were deleted. To confirm data saturation, each member additionally coded a transcript each, no new codes were identified. After a consensus for the final list of codes was reached, the author coded all sixteen transcripts using the common code-book. Any new codes identified was discussed by the research team and re-grouped or added to the list as deemed appropriate.
The follow-up interviews were coded by the author alone as this was only a 10 minute interview with Yes/No questions inquiring changes in driving habits and reasons for inaction.

5.2.1 Demographics, Scores and Survey Responses

The demographics of the participants interviewed in Phase-1 of the study are listed in the Table 5.1. Their age, gender, whether they are the primary or occasional driver of their household and their driving experience in years were recorded. The participant's scores on the the three tasks they performed as part of the cognitive walk-through were recorded and are listed in the Table 5.2. The ratings given for each aspect of *SmartDrive 1.0*: usefulness, usability and design, in the surveys presented to the participants at the end of the walk-through have been listed in Table 5.3.

Table 5.1: Demographics and driving experience for participants in Phase-1 interviews (n=16).

Participant	**Age (yrs.)**	**Gender**	**Driver**	**DrivingExperience (yrs.)**
P1	69	Female	Primary	53
P2	75	Male	Primary	54
P3*	73	Male	Primary	57
P4*	70	Female	Occasional	53
P5	82	Female	Primary	57
P6	77	Female	Primary	58
P7	65	Male	Primary	49
P8	72	Female	Occasional	55
P9	84	Male	Occasional	65
P10	76	Male	Primary	60
P11	82	Male	Primary	66
P12	68	Male	Occasional	50
P13	76	Female	Occasional	60
P14	73	Female	Primary	55
P15	74	Male	Primary	54
P16	73	Male	Occasional	58
Average	74.31	—	—	56.5
Std Dev.	5.06	—	—	4.55

* indicates callbacks from pilot study.

Table 5.2: *SmartDrive 1.0* task scores and responses from self-rating questionnaire for the Phase-1 interviews (n=16).

Part.	**Mazes (sec)**	**TMTb1 (sec)**	**TMTb2 (sec)**	**UFoV (msec)**	**Self-Rating**
P1	8	83	n/a	133	Go
P2	6	84	n/a	516	Caution
P3	7	51	n/a	67	Go
P4	5	89	48	516	Go
P5	7	80	73	466	Caution
P6	14	85	n/a	116	n/a
P7	7	47	37	67	Caution
P8	5	51	30	83	Go
P9	7	51	n/a	316	Go
P10 (Desktop)	7	66	n/a	67	Caution
P11	n/a	227	89	183	Go
P12	7	53	39	116	Caution
P13	12	49	62	516	Caution
P14	10	57	n/a	516	Go
P15	10	138	119	266	Caution
P16 (Desktop)	15	116	n/a	533	Caution
Average	8.47	82.94	64.14	279.81	—
Std Dev.	2.99	44.92	29.87	190.82	—

'n/a' in Mazes indicates participants who were unable to perform the task due to Zoom/ application malfunction. 'n/a' in TMTb2 task indicates those participants who did not choose to repeat the task a second time. 'n/a' in Self-Rating was due to the participant not filling out the entire questionnaire. P10 and P16 used desktops with mouse and keyboards while the rest used tablets with touch screens.

Table 5.3: Participants' Usability and Usefulness Ratings of *SmartDrive 1.0* for Phase 1 (n=16).

P.Code	**Perceived Usefulness**		Perceived Usability		Interface Design	
	Score	Useful	Score	Usable	Score	Design
P1	64	Agree	67	Agree	86	Agree
P2	61	Agree	62	Neutral	43	Agree
P3	93	Agree	98	Agree	82	Agree
P4	100	Agree	96	Agree	93	Agree
P5	100	Agree	67	Agree	79	Agree
P6	50	Neutral	40	Neutral	29	Neutral
P7	89	Agree	69	Agree	68	Agree
P8	61	Agree	60	Neutral	75	Agree
P9	86	Agree	54	Agree	68	Agree
P10	75	Agree	65	Agree	82	Agree
P11	82	Agree	79	Agree	71	Agree
P12	75	Agree	75	Agree	89	Agree
P13	50	Neutral	42	Neutral	29	Neutral
P14	50	Neutral	40	Disagree	54	Disagree
P15	82	Agree	58	Agree	89	Agree
P16	75	Neutral	65	Agree	50	Disagree
Avg	74.6	—	64.9	—	67.9	—
Std Dev.	16.5	—	16.5	—	20.3	—

A score of 100 indicates strong agreement to all positive statements and strong disagreement to all negative statements about the interface.

5.2.2 Phase-1: Emergent Themes

There is overlap in some of the themes identified in the pilot study and the Phase-1 interviews, however several new themes emerged. The categorisation for Phase-1 themes was suited to the FITT model (i.e., **F**it between **I**ndividuals, **T**ask and **T**echnology) which is a previously established variant of the Technology Acceptance Model [4]. The FITT model (See Fig. 5.2) discusses the optimisation of the user, technology and the task 'fit' together in their interaction. The task here is not to be confused with the cognitive tasks in the assessment application but the outcome of using the application, which would be for *SmartDrive* versions a change in driving habits or the follow-up activity that is safe and suitable for the user's situation. Several applications have employed this framework to test the efficiency and effectiveness of their designs [88], [52]. For this analysis however, a chronological order was found more suitable to the findings and was implemented in the final categorisation of themes.

Using the FITT model as a guide, the overarching themes that emerged from the analysis of Phase-1 interviews have have been categorised into the three aspects that are mentioned in the model (See Fig. 5.3). In Part 1 of the model, the User, their needs and perceptions or preconceptions that they approach the technology with, are explained. In Part 2, the App or Technology and the aspects pertaining to the user's interaction with it (*SmartDrive 1.0*) (e.g., usability, accessibility, cognitive tasks and feedback) are examined and finally In Part 3, App effects or takeaways (follow-up activities) that user gained from the interaction with *SmartDrive 1.0* and the factors that influence it (perceived credibility) are observed.
Tables 5.4, 5.5, and 5.6 list all the themes that were identified, the new ones that emerged from Phase-1 analysis have been highlighted in magenta, those that have not been highlighted were identified in the previous pilot analysis (See 4.6).

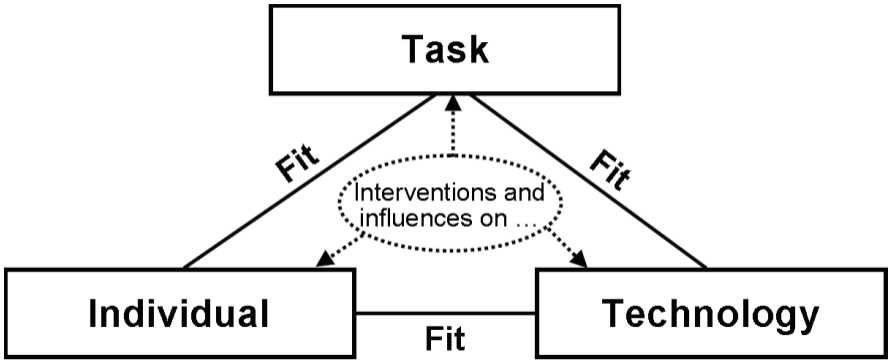

Figure 5.2: The depiction of the three interaction aspects of the FITT framework widely used for usability testing, **F**it between **I**ndividuals, **T**ask and **T**echnology [4]

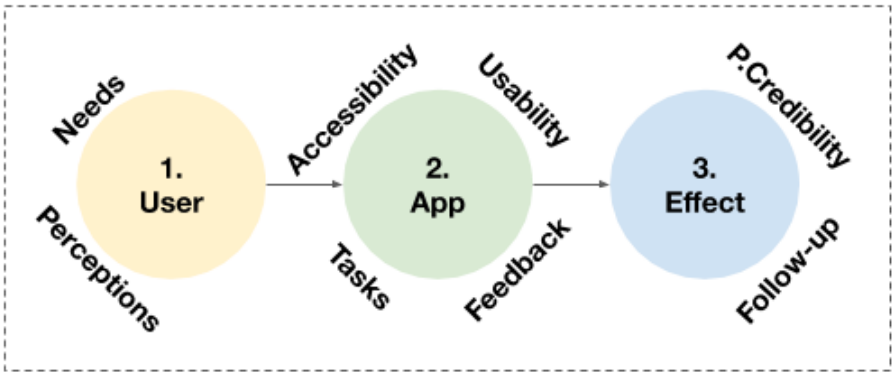

Figure 5.3: Three categories of the themes and the corresponding themes that emerged from Phase-1 interview analysis

Part 1. User/Individual

The focus of the two themes under this category are the needs identified and the perceptions that the user already has before interacting with the app. This category aims to address the characteristics and requirements of a potential user as well as preconceptions that would affect their experience with the application. The Table 5.4 below lists the two overarching aspects of a potential user along with the relevant sub-themes identified. The prevalence of each sub-theme is demonstrated by recording the number of participants (out of a total of 16) who mentioned that particular sub-theme. This allowed us to recognise themes that were more frequent and hence significant to the target user. The sub-themes that we encountered and have explained previously in the pilot study (see Section 4.3.2) have been mentioned only in passing, the novel additions from this Phase of research are discussed in more detail.

Table 5.4: List of themes and sub-themes that were identified through analysis of Phase-1 interviews and fall under Part 1 of the FITT framework (i.e., The User/Individual). New themes from Phase-1 analysis have been highlighted in magenta.

Theme	**Sub-theme** (Prevalence; n-total = 16)
A. **User Needs**	Understanding Driving Ability (4) Maintain or improve driver safety (10) **Monitoring driving or cognitive abilities** (11) Maintain Autonomy (4) **Recognise when to stop driving** (11)
B. **User Perceptions**	**Self-perceived Driving Ability** (9) Awareness of Ability Decline (12) **Importance of Early Planning** (4) **Perceived App Purpose** (10+)

Part 1A. User Needs

This theme encompasses the needs of the target user that were identified in the context of their driving. We observed a significant overlap with the pilot theme *Motivations for*

Use, especially for sub-themes with higher prevalence. The need to *Maintain Autonomy*, to improve driving *Safety* and the intent to learn/know more about their abilities (Curiosity) were observed previously in the pilot interviews as well. However, two new sub-themes have been identified that did not previously emerge and have been explained below.

1. **Maintain Autonomy: Driving & Decisions**
   Although 'Maintain Autonomy' was previously captured as a pilot Theme, in Phase-1 there was an additional focus on the decision about driving cessation rather than only the ability to drive. Participants disliked the idea of a loss of independence that can come with deciding not to drive anymore, but also wanted to avoid having their license revoked. A few stated that this would be easier with the help of appropriate information about their current and changing abilities.

   P5: *"The idea of losing my license is perhaps one of the most scary because I'd lose my independence...lose some of the control in my life."*

   P4: *"The worst thing that happens when you're going into this portion of your ageing journey is having control taken away from you...it's much better to be offered choices with some guidance."*

   P16: *"It takes an ability to realise what your cognitive abilities are for you to make that decision. By the way it can't be someone else's decision that you are forced into, you are always going to rebel."*

   P11: *"...if I want to quit driving, I want to quit on my own."*

2. **Monitoring driving or cognitive abilities**
   The need to track changes in driving ability or cognitive skills related to driving was mentioned by 11 of the 16 participants. Participants explained and emphasised how this would help them in monitoring their abilities with time and make informed interventions if and when needed either to adjust their driving habits (go slower/avoid certain situations) or even in some cases stop driving and hand over the keys to their spouse.

   P12: *"There would certainly be some history (scores) to show a [age-related] decline and that might help take action if the decline was substantial...see the changes over time."*

3. **Recognise when to stop driving**
   The need to be able to understand and recognise for themselves if and when they should discontinue driving was prevalent. The majority of the participants mentioned that they would be able to intuitively estimate at what age or time of their driving career, driving cessation would be necessary. Similar to the pilot sub-theme 'Wake-up calls' they also mentioned 'indicators' that would assist them in identifying if they were unsafe on the road and should discontinue driving. Comments from passengers in the car, family or friends about their driving were stated as reasons to re-assess their driving. In addition to this, *SmartDrive 1.0* was considered to be a viable way to support this purpose. 11 of the 16 participants mentioned the need to recognise when to stop driving as part of the process of **maintaining autonomy** in the decision about their driving.

   P2: *"One thing I am aware of is that I should acknowledge that I am getting to the age that I shouldn't be driving...I hope I have the common sense to stop driving [when it is needed]."*

   P10: *"Well, I would say if I have a lot of near misses and if I don't see somebody, or a car or something, if this is happening quite a bit - if I miss a lot a stop signs then...[will stop driving]"*

   P5: *"Well certainly, if I questioned myself, I would stop [driving]. Probably what would make me think about it more would be when my friends and relatives tell me something about it."*

   P7: *"I don't ever want to wait to the point where I have an accident to realise that there's something wrong with my driving...I'm often driving my wife and or one of my daughters around, I'm sure they'll speak up and let me know if my driving is starting to suffer, like I did with my own mother."*

Part 1B. User Perceptions

This theme is an addition to the previous list of pilot themes; namely, new concepts that appeared in the Phase-1 analysis. It is a collection of the preconceptions that the user possess before interacting with the application.

1. **Self-perceived Driving Ability**
   This sub-theme reflects the participants' prior perceptions they held about their driving before interacting with the application. This included their intuitive confidence and comfort in driving or any specific concerns they had about their driving which affected the adjustments they were making to their driving. This belief about their driving was identified as one of the primary influencing factors for a need and adoption of a self-assessment application.

   P2: *"I think I am a competent driver and I drive all over the world - in the UK, US, Europe. At the moment I am fully confident in my ability to drive and I feel I am a long way from when I should not be at the wheel of a car. But an app like this on a regular basis would give an indication that maybe I shouldn't be driving."*

2. **Awareness of Decline in Ability**
   An important user perception that was noted was if the older adult driver was cognisant of the possibility of age-related cognitive decline, more specifically aware of any deficiencies in their driving-related skills. As mentioned earlier (See Section 4.6) this awareness not only allowed the participants to understand the need for re-evaluation of their driving skills, but also prompted them to actively make necessary changes in their driving to compensate for declining ability in an effort to increase their and others' safety on the road. This was a significantly prevalent notion, with 12 of the 16 participants agreeing to the possibility of age-related decline and their concern for driving safety in the future. Seven participants mentioned the details of adjustments to driving habits they make to ensure safety.

   P12: *"I try to avoid it [driving in the night] because I'm conscious of the fact that my [night] vision isn't that good...my ability to discriminate...downtown area, so many lights, difficult to discern traffic lights with neon signs. I only noticed that in the last few years. I don't want to be in a situation where I miss a red light because I thought it was a store sign."*

3. **Importance of Early Planning**

One of the features of *SmartDrive 1.0* was the prompt to early planning for driving cessation. While four of the participants had positive reactions to the idea of early planning, the rest of the participants had not considered this as an option. A few did not believe it was necessary or relevant to their situation in life. A few stated that because of the uncertainty of ageing and cognitive decline, driving could not be predicted and planned for. There were also social and subjective norms that dictated their perceived importance of planning, especially: (1) whether their peers had begun planning, and (2) age limit set by the Ministry of transportation for mandatory re-licensing.

P4: *"A couple of years go by quickly, so maybe you need to start considering a plan. They tell you to pre-plan your funeral, all end-of-life things. You need to plan your finances after you have retired, well this [advance planning for driving cessation] is another thing that could well be something you should be looking at too."*

P6: *"I don't know anybody that I know of who has done any forward planning as far as driving in the future. I think we all deal with that when the day comes, you know, there's not much point in forward planning. You either drive or don't drive."*

4. **Perceived App Purpose**

This sub-theme encompassed the expectations that the older adult had about *SmartDrive* and was identified as a factor that affected their perceived usefulness of the application. Since this question was explicitly asked (See Appendix F, Question 2), all participants expressed what they thought. However, 10 of the 16 participants later mentioned that the app had partially or fully satisfied the needs and expectations they had prior to interacting with it.

P5: *"[purpose of the application was to] keep everybody on the road safe, myself included. Self-knowledge is always a good thing, we learn every day, and today I learned that my driving wasn't as up to standard as I thought it was...made me more aware of my driving habits and ways I could improve them."*

Part 2. App/Technology

The themes under the "App/Technology" category are related to aspects of the design of the application. Unlike the previous inductive sub-themes (mentioned independently by the interviewee), some of the these sub-themes were deductive (predefined by the interviewer); every participant was asked about and gave their preferences/opinions on these pre-defined aspects. The prevalence for deductive codes would be 16 and would not be worth noting, thus the number of positive and negative reactions are recorded instead. For those sub-themes that were inductive, the prevalence is stated adjacent to the sub-theme in the Tables 5.5 and 5.6.

Positive reactions were defined as explicit exclamations/remarks/statements made indicating the participant's preference or liking to the design aspect either as part of the think-aloud protocol or as a response in the interview. Negative reactions were defined as explicit statements/exclamations/remarks made indicating their dislike towards the design aspect either as part of the think-aloud protocol or as a response in the interview. Any non-comment, indecision about preferences and dismissive remarks without explicit statements were considered as neutral statements.

This category (Part 1: App or Tech), in general encompasses the various design aspects, limitations and the participant's impressions of the tasks, feedback and more.

Table 5.5: Themes and sub-themes that were identified through analysis of Phase-1 interviews that fall under Part 2 of the FITT framework - App or Technology. New themes from Phase-1 analysis have been highlighted in magenta. Prevalence is only mentioned for themes derived from inductive codes (i.e., occurred organically) whereas positive, negative and neutral reaction numbers have been noted for deductive sub-themes (i.e., all participants were explicitly asked about).

Theme	**Sub-theme** (Prevalence)	Positive	Negative	Neutral
A. Usability	**Modality (audio/video/haptic cues)**	-	5	11
	Colour & Contrast	1	1	14
	Wording	-	-	16
	Layout and Navigation	4	2	10
B. Accessibility	Type of device (9)	-	4	12
	Technical Smarts (5)	-	-	16
C. Tasks	**Perception of Complexity**	2	11	3
	Instructions	3	13	-
	Engagement (8)	8	-	8
	Reflect cognitive changes	11	-	5
	Task Randomisation (3)	-	3	13
D. Feedback	Presentation Style	10	4	2
	Usefulness of recommendations (13)	9	4	3
	Improved understanding of skills (14)	12	2	2

Part 2A. Usability

This sub-theme explores the overall interface of the application. Five of the sixteen participants mentioned that the cues presented during the practice and task sessions were insufficient and needed to be improved. This was particularly an issue for the final task (UFoV), which is discussed in the later sub-themes (Section 5.2.2, Part2C. Tasks, Item 1: Perception of Complexity). The colours and contrast of the fonts and graphics used were mostly neutrally received, one participant expressed explicit like and another dislike towards the visuals of the interface. The wording throughout was mentioned as important but there were no specific instances of critique or praise of the language used in the application. Finally, the layout and navigation that involves the design of buttons, positioning of information, screen to screen transition in the app was received well and considered easy by four participants and difficult by two. The others only had neutral or no comments.

The two negative instances were about feeling number of the screens were too crowded and the layout of the feedback which had scores and suggestions on the same screen. A comment about the need to reflect and understand scores first, after which suggestions would be sought, was made and the two sets of information were later separated to allow time for reflection on the scores in the tasks.

P2: *"It was pretty good, I suppose brighter colours might be better. It was fair enough, wasn't too complex. Good that you did not have a fussy interface - otherwise that would just be a distraction."*

Part 2B. Accessibility

This theme discussed two aspects: 1) the accessibility of a tablet and 2) how comfortable older adults were using it. Both these aspects were previously captured in the pilot as *Availability and familiarity with the device* (See Table 4.6). The negative instances recorded in this set of interviews related to the size of the tablet screen and how in some cases was not large enough to display information with optimal clarity (the application rendered the font too small to fit the screen of the mini-iPads). Four participants mentioned the issue with their fingers blocking the view of the maze partially while they moved the circular dot. This was inherent to tablets and can be potentially changed with a mouse and desktop inputs. *Technical Smarts* was also mentioned as one of the

barriers of using the application. Despite the fact that most of the participants owned a tablet, 4 participants (especially those above 80 yrs.) mentioned that they were not comfortable using it.

P6: *"I mean I'm not as comfortable on a touchscreen as on a computer with a mouse, I honestly would have felt more comfortable doing that. There were a few technical things on the touchscreen that I was not comfortable with."*

Part 2C. Tasks

This theme was not explored previously in the pilot analysis since only one task was implemented in the pilot version. Each of the tasks were discussed with all participants. Three aspects in particular were examined using deductive codes (i.e., pre-defined points of discussion that were uniformly inquired about with all participants). These were (1) Perception of Complexity, (2) Instructions and (3) Reflect cognitive changes. The two other aspects naturally emerged as inductive codes (independently mentioned by participants without prompts) were (1) Engagement and (2) Task Randomisation.

1. **Perception of Complexity** Three participants found the mazes to be too simple and this was reflected in the Perception of Complexity. A total of 13 participants required additional explanation for the UFoV task, which was likely because this task had multiple stimuli at different locations and the wording of the instructions were not clear to a majority of the participants. This perceived complexity was reflected in the negative reaction to 'Instructions' presented as well. UFoV was deemed too challenging by many, which was in part due to lack of clarity in the task instructions, making it appear more complex than it was.

   P9: *"I didn't find it [mazes] heavily challenging but it was challenging and I quite enjoyed doing it."*

2. **Instructions** 13 participants mentioned that the instructions presented for the UFoV task were insufficient and needed to be improved. The remarks were generally directed towards lack of comprehensibility of the instructions and in some cases even misunderstanding of what needed to be done. The instructions for the other two tasks (Mazes and TMTb) were deemed clear and sufficient.

P2: *"My biggest problem was I didn't get in my own head what I was supposed to do when it [UFoV] was running. Maybe if I get it a few more practice times, I might understand it."*

P6: *"Hmm the car and truck thing, that was um - I don't know how you determine the timing on that but that was a little awkward to work through...frustrating."*

3. **Engagement** Eight participants stated that they enjoyed some of the tasks and found them sufficiently challenging. Mazes were especially preferred and even prompted a nostalgic anecdote in a few as they recollected instances from their childhood about enjoying mazes.

   P15: *"Once I understood what I was doing, it was good - I enjoy stuff like that."*

4. **Reflect cognitive changes** When asked if the tasks would help the user track any changes in their cognitive and driving abilities, eleven enthusiastically agreed to the premise. Three stated their reluctance to agreement was that the need to randomise the tasks every time the user returned to the application to ensure validity in assessment.

   P4: *"Yes, I think it [application] will, it is set up well to do that [reflect changes in ability]...[makes older adults] realise "Oh wow, I am really not what I used to be, I need to reconsider my driving." and change the way they do things."*

5. **Task Randomisation** The possibility of higher scores as a result of over-familiarity with the task rather than improvement in skill was mentioned.

Part 2D. Feedback

While 10 of the 16 participants liked the general presentation style of their performance-feedback, four suggested changes to the layout. Two of the participants wanted more information about the metrics used for scoring and the other four participants suggested separate screen for visual graphs of the scores and the recommendations. The layout was designed to include a central hub of information; having all three task summaries and

options to consider but suggestions for sequencing the two sets of information was mentioned. Nine participants mentioned that the recommendations presented were useful despite being familiar to them as a refresher. Four suggested on expanding the list to cover other options available. A few did not find some of the recommendations suitable or appropriate for their scores. As mentioned in Section 4.5: Design Modifications, Table 4.11, the design avoided a one-on-one mapping of score and feedback, a general list of options was shown and the user was encouraged to choose the options that would suit them best. *Alternative transportation* and *Chat with physician* were considered premature by many regardless of their scores.

12 participants mentioned that the feedback from the tasks improved their understanding of their skills while two mentioned they did not acquire new knowledge from the tasks but did find the suggestions useful.

P4: *"They [suggestions] were useful...I think you covered it pretty well. It's good to have them sitting there and looking at you. So then you say, 'Oh right, I knew that and I should have done that.'. And it was good have them to read and reinforce."*

P4: *"I'm shocked how poorly I did with the last challenge (task) and now I need to look it up - that's a big part of what the idea is. Maybe if it gives us a bit of a wake-up and shake-up, maybe we would go out there and do something about it."*

P3: *"It gave me food for thought...it was a bit of an eye opener, not in the way that my driving skills are good or bad, it just gives food for thought. The application makes you aware that if you're missing one aspect of your cognitive skills, it would be disastrous. Those three tests were very very good, you can feel yourself having to process what you have to do."*

Part 3. App Effects

Two themes captured the effects of the application experience on the user's driving habits. Participants' responses to the feedback they received first addressed their *Perceived Credibility* of the application, which influenced their perceived need to act on the feedback and scores. The activities that the users considered among the several options suggested by the application has been noted in the sub-theme, *Follow-up activities*.

Table 5.6: List of themes and sub-themes that were identified through analysis of Phase-1 interviews and fall under Part 3 of the framework: App Effects. New themes from Phase-1 analysis have been highlighted in magenta. Prevalence is only mentioned for themes derived from inductive codes whereas positive, negative and neutral reaction numbers have been noted for deductive sub-themes which all participants were asked.

Theme	**Sub-theme** (Prevalence; n-total = 16)	Positive	Negative	Neutral
Perceived Credibility	Respectful Tone (5)	2	-	14
	Results Dissonance	2	4	10
	Acceptance of Results	13	3	-
	Relevance to Driving	14	2	-
Follow-up activities	**Explore a Driving Plan**	7	3	6
	Explore Cognitive Exercises	5	-	11
	Connect with Professionals	4	12	-
	Revisit Application	13	3	-
	Increase Alertness in Car	11	-	5
	Take a Driving Course	4	-	12
	Discussion with family or friends	12	-	4

Part 3A. Perceived Credibility

This sub-theme was previously captured as *Trustworthiness* in the pilot study. With a larger sample size, we were able to expand on the factors that influenced the user's trust in the application

1. **Results: Dissonance & Acceptance**
   Unlike in the pilot, this version of the prototype included a question prompting the user to predict their results. We then explored the amount of dissonance in the expectation of results vs. the reality. A majority of the participants correctly predicted their scores, six participants mentioned that they were surprised by their results. Four had negative reactions where they stated that they expected to perform better but received lower scores and two mentioned that they were pleasantly surprised to have performed better than they had expected. Overall, six participants received scores different from what they had expected. Two were pleasantly surprised to have scores higher than expected while six received scores lower than expected stated that the results were an inaccurate indication and did not agree with their scores. 10 participants accepted the scores they had received and did not indicate any dissonance and had expected their performance accurately.

   P12: *"Hmm (long pause) I'm just trying to think this through here because I don't feel that that was a fair assessment, unless my cognitive ability is a lot less [than I expected]"*

2. **Relevance to Driving** Of the sixteen participants, 14 expressed a range of strong to weak correlation of the tasks in the application to driving. A majority enthusiastically drew connections between UFoV task and spotting objects in the rear view mirror on the road while driving. Many parallels were drawn between tasks and driving. Two participants did not feel there was a connection between any of the tasks with on-road driving. This was addressed in the latter version of the prototype (i.e., *SmartDrive 2.0*) with additional study references and explanations regarding the tasks.

   P6: *"I don't think this kind of thing truly effects one's driving ability. It's a whole lot different to be doing the test on the screen than to be actually driving a car, I think."*

P9: *"You've got to be able to look ahead to see what is going on but you also have to know what is going on around you too, see all the traffic, the cars beside you and whatnot. Yes, I think it [UFoV] is significant for driving."*

P4: *"So you are looking at the centre and you see the car and truck, and as quickly as you register that, you also have to know your surroundings. Like a small child coming on the street - you need to see where it is, where it's coming from, and how fast it is going and all those things are tied together in that [UFoV]."*

P15: *"I found that, once I understood what I was doing, it became a little easier. You can see that your brain doesn't work as quick as it used to be, eye-brain coordination...that's critical in driving - be able to see a situation that you encounter when you're behind the wheel and how you react to it."*

Part 3B. Follow-up activities

As mentioned in the design development and modifications section (Section 4.5), a general list of follow-up activities were presented to the user following the feedback screen. This general list was uniformly presented to all users irrespective of their scores in the three tasks. The following items present the number of participants who considered or did not consider the suggestions presented as part of *SmartDrive 1.0*'s feedback design.

1. **Explore a Driving Plan**

   The idea of advance planning for driving cessation did not resonate with many of the participants. Three of the participants did not believe this to be useful, one of the reasons stated was the uncertainty of changes in cognitive skills as one ages, the unpredictability of how the future was stated as a reason why early planning would not be relevant. Although 10 participants stated that the application prompted the idea of planning for their driving futures and brought this to the forefront of the discussion about driving, only 7 positively stated that they would consider this further.

   P7: *"Yes, what it [application] did...confirmed in my mind that I'm doing well now. But it also brought into my mind, if I don't continue to do okay, if I continue doing this test every year and I see the numbers go down, then it makes me think that I'll have to start planning ahead for the day I'll have to stop driving."*

2. **Cognitive Exercises**
   Several participants liked the *Brain Training* suggestion presented to them, this seemed to align with our previous finding in the pilot Sub-theme *Seeking Improvement*. Eight participants mentioned that they would consider online exercises to improve their reflexes and vision through regular exercise.

   P1: *"My next step would be to check on the computer what kinds of cognitive things might be available and um speak with my doctor about the same one. Does he have any cognitive testing that he could do or does he have any suggestions on what would improve my cognitive abilities."*

3. **Connect with Professionals** A majority of participants stated their intention to talk to professionals (i.e., physicians, optometrists, or driving instructors) weren't necessary for the their current state of abilities, but would consider it in the future. Five participants mentioned that they would schedule appointments with their optometrists to talk about their scores in the UFoV test.

   P5: *"With the last test I would like to see them better, so the next steps would be going to the optometrist and getting my peripherals and eyesight checked in general."*

4. **Revisit application**
   13 of the 15 participants mentioned that they would be willing to use the app again, the reasons stated inclined towards the desire to monitor changes in scores over time.

   P10 *"I would be quite happy to do it again once a year to see how I'm doing. It's giving you a quantitative level of certain skills and it's always easy to compare."*

   P2 *"Yes [willing to use application again]...I would do it on a regular basis just to measure...see if I'm getting better or worse. Am I getting to the point where I would reappraise my ability to drive?"*

5. **Increase Alertness in Car** Several participants explicitly mentioned that their lower scores prompted them to be more alert in the car while driving. 11 participants of the 16 stated that they would be more cautious during left turns and on highways, when slower reaction times would be a high risk. Similar adjustments to driving were stated and although these have limited impact on driver safety, they were a positive indication of steps in the right direction.

   P12: *"I'm now more aware of the possibility, because it's not absolutely known, but certainly a possibility that my reflexes to peripheral events may not be good enough, I'm alluding to the third test. So maybe I need to slow down a bit when I enter intersections...drive slower at night."*

6. **Driving course** Four participants acknowledged that a driving course would be beneficial and would potentially consider it if their scores were lower (i.e., in critically below average levels), but none committed to the idea for the fear of losing their license. The need for an unbiased third agency was discussed since the threat of losing license seemed more severe when transportation or medical authorities were involved.

   P12: *"If there's a cause for concern, maybe the first step would be to take the test again in a week. Then the second step would be to talk with the doctor or another third party (e.g., driving instructor or agency). There should be some way to pursue it without the threat of having your license taken away."*

   P8: *"...taking a driving refresher course is probably not a bad idea, but will I get around to taking one? Unlikely. But yes, it's definitely a good idea."*

7. **Discussion with family or friends** 12 participants mentioned their intention to share the results and feedback they received with their family, (especially a spouse) or close friends. As mentioned previously, this would not necessarily cause changes in driving, but it indicates a discussion about any driving errors currently made or exploring potential plans for alternative transportation.

P16: *"I will talk to my kids and I will talk to my wife...about the results and that I might need some help at some point as in driving assistance. Finding someone else, alternate drivers wouldn't be difficult."*

5.3 Analysis of Phase-1 Follow-up Interviews

As was done in the pilot study, the impact of the application on driving behaviour of the participants was gauged using follow-up interviews two weeks after exploring the Phase-1 prototype. 15 of the 16 participants were called back exactly two weeks following the study. While one participant was contacted multiple times, they did not respond to calls or emails and so data for the follow-up interviews was absent for this participant.

Similar to the observations from the pilot follow-up interviews (See 4.7), eight participants discussed the application or their driving with a member in their social circle. A majority specified this member as their spouse. The app was able to prompt the idea of early planning in seven of the 15 participants, this plan included a range of options that were presented in the application: one participant scheduled an appointment with a driving instructor, another asked their spouse to take over the driving. Both those participants stopped driving and scheduled an appointment with their optometrists as well. Both changes were stated as a direct result of receiving lower scores in the application. Five participants stated the application helped them in acknowledging the need for a plan and while no details were discussed, all of the five mentioned that they would consider one in the future. This was the highest increase in responses seen from pilot study. Approximately half the participants mentioned that their experience with the application made them think more critically about their driving and provided them with possible ways to improve their safety as a driver. 10 participants mentioned that the application had positive impacts on their driving style and/or driving perception: average and above scores increased their confidence in driving (n=1), relatively lower scores prompted the drivers to be more alert and aware in the car (n=9). The latter included double-checking the rear-view mirrors, slowing down if needed to compensate for slower reaction times and avoiding driving in risky situations. 12 of the 15 participants were enthusiastic about the prospect of using the application for self-assessment in the near future. Many stated curiosity about changes in scores as a main reason for re-use.

Table 5.7: Follow-up interview responses of participants who were called back two weeks post their Phase-1 interviews (n=15).

Possible Action Plans	Positive reactions	Negative reactions
Discussion about application or driving	8	7
Explore a driving plan	7	8
Self-introspection about their driving	8	7
Impact of app on driving	10	5
Willing to repeat app-use	12	3

5.4 Design Modifications

Based on the feedback received and the emergent themes, the application was further modified into the next version, *SmartDrive 2.0*. Modifications to address sub-themes are explained in Tables 5.8 & 5.9.
The final version of the SmartDrive prototyping process, *SmartDrive 2.0*, that was tested in Phase-2 can be found at
https://v2.smartdriveuw.com/

5.4.1 *SmartDrive 2.0*: Wireframe

As seen in the Fig. 5.4, after the introductory screen [1. Welcome Screen] similar to *SmartDrive 1.0*, the user is presented with the option to view the references for studies that have explored and confirmed correlations of the tasks to on-road driving performance [2. More Information]. (identical to *SmartDrive 1.0* See Fig. 4.3). Following this, three options as seen earlier in the pilot version (See Fig. 3.5) are presented to the user [3. Sign In], [4. Play Now] and [5. Sign Up]. All three screens lead to a screen listing the three tasks that can be performed [6. List of Tasks]. All three tasks can be performed sequentially [7-7a, 8-8a, 9-9a]. The instructions and practice options have been modified as described in Fig. 5.8. After completion of all three tasks, a Pause and plan screen appears. Text inputs have been removed and the user is then asked to consider what their next-steps might be if they receive scores lower than what they expected.
A combined screen [11. All 3 tasks summaries & suggestions] including the overview of user's performance in all three tasks is presented without any suggestions. The user also has the option to view detailed individual summaries for each of the tasks [11a, 11b, 11c] (including user scores, threshold scores, etc...). These are optional to the user who is interested in the information and can be skipped. The user can proceed to the list of suggestions [12. *SmartDrive*'s Suggestions] that are presented sequentially (See Table 5.9 for details of the list), which the user can read and select to record. Finally another screen [13. Create your own plan] encourages the user to create and draft their possible next-steps after having viewed their scores. The user can also revisit the suggestions to refer to possible options. The last screen [15. Email Session Package & Exit] provides the op-

tion to choose to email the session package to themselves or the user can choose to simply exit the application.

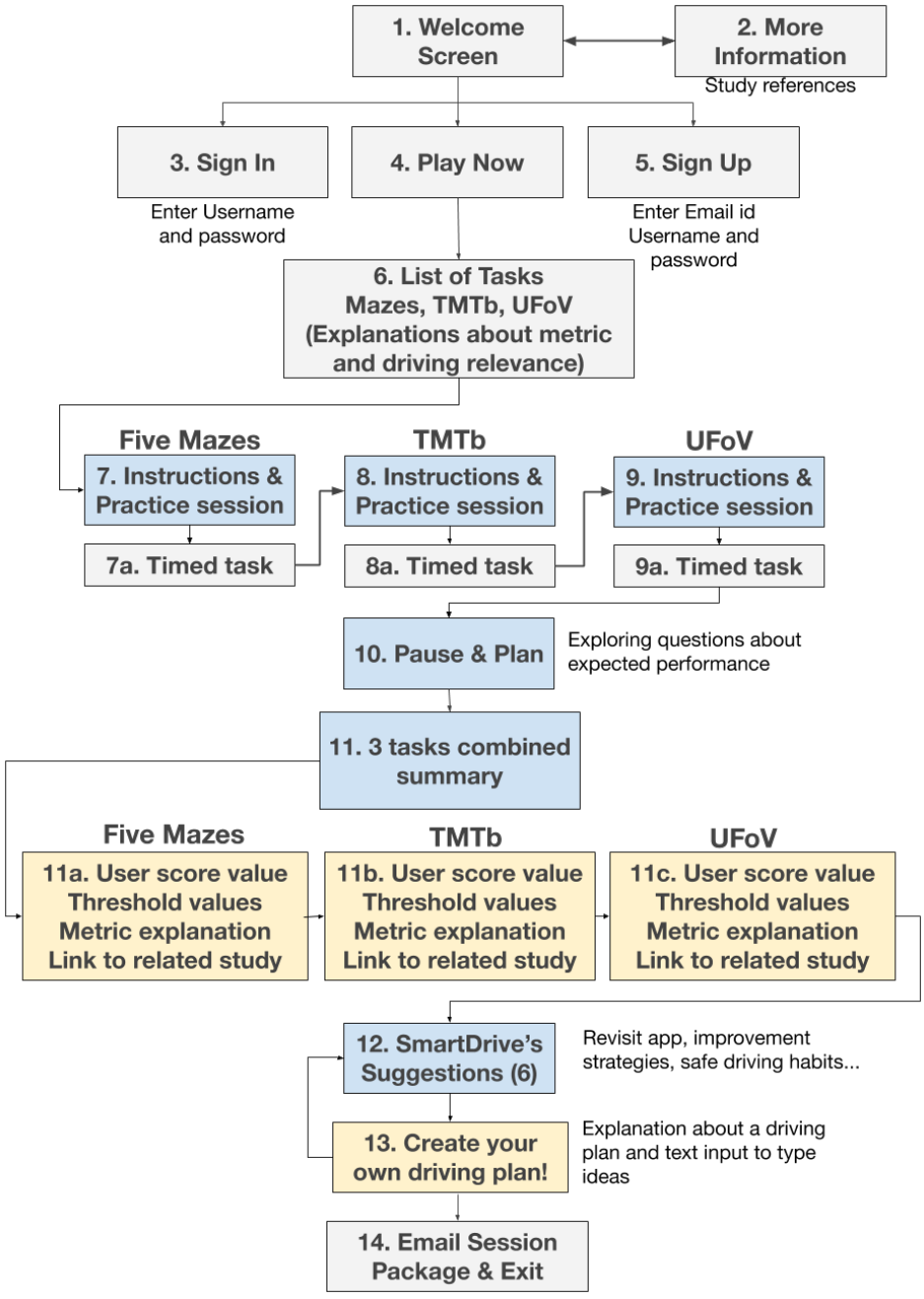

Figure 5.4: Sequence of screens presented to the user in *SmartDrive 2.0*. Screens highlighted in blue are those that present in *SmartDrive 1.0* version but have been modified and yellow boxes indicate new additions to *SmartDrive 2.0*.

Figure 5.5: Changes made in task instructions to improve readability. Red circles indicate the location of changes, which include: (1) Maze start and finish prompts, (2) Trails: additional hint, (3) UFoV: step-wise instruction format.

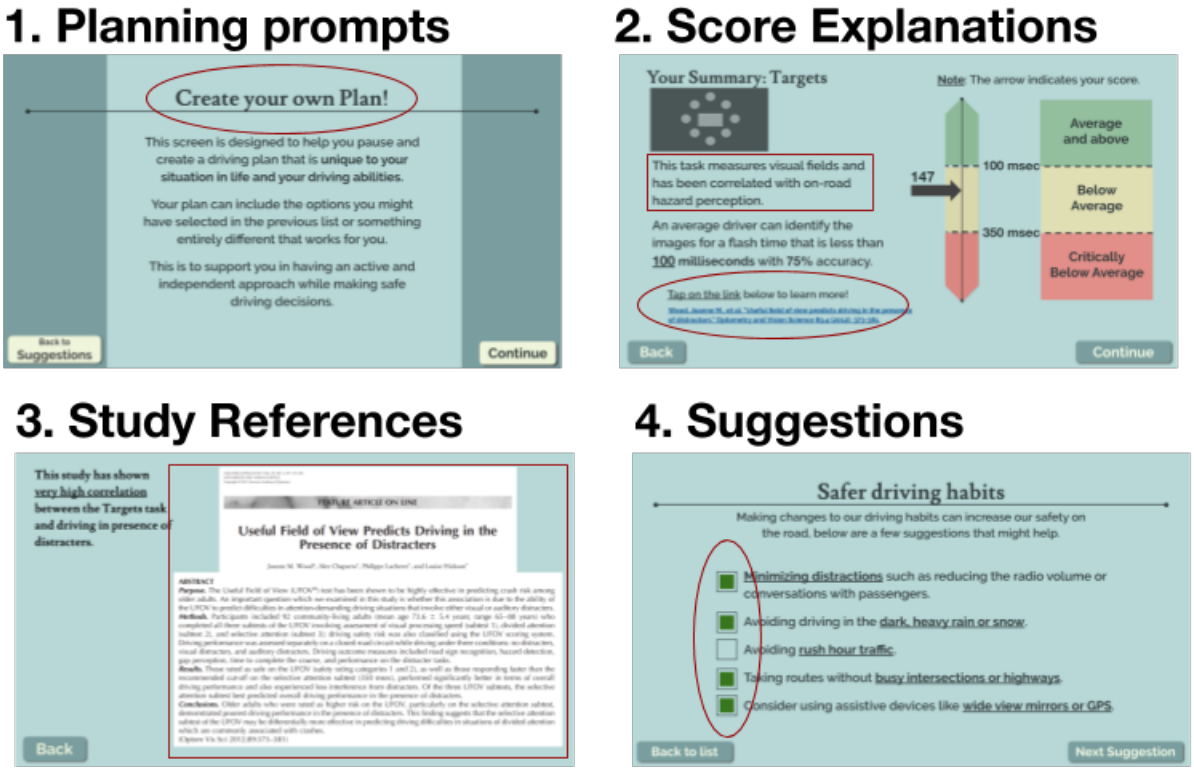

Figure 5.6: Changes made to improve credibility and usefulness of suggestions. Red circles and boxes indicate the location of change for: (1) planning prompts at the end of the app, (2) Score explanations, (3) Study references to increase perceived credibility, and (4) radio buttons to select and record suggestions.

Table 5.8: Design changes that were made to address the sub-theme *Instructions* in *SmartDrive 2.0*

Sub-theme	**Design Edit**	**Rationale**
Instructions	Multi-step instructions format	The process of sequential selection of central and peripheral target (car or truck) was explained using layered steps. The user is presented an image of what the screen would look like with instructions in text below, they are asked to click on the button to see the next step and so on.
	Choice for multiple practice sessions	A maximum of 600 milliseconds display time for the flashes in UFoV task is maintained during the practice sessions. Repeating the task several times at 600 ms would not affect the participant's responses to a faster flash time (i.e., <600 ms) but would help increase understanding of what needs to be clicked when.
	Additional hints	Start and finish prompts in all mazes were added, additional instructions for trail making regarding tapping buttons to draw a line was clarified to avoid confusion. Additional instructions were given to eliminate any misinterpretations of the task. The additional prompts in the mazes although modified the original test design, these were hypothesised to compensate for the delays caused due to the nature of administering the test on a tablet where the finger (to move the circle through the maze) partially blocks the user's view. The prompts (labels and arrows) were added so that the user could still spot where they needed to get to while keeping the finger on the maze, however, this modified digital version of the test changes the overall validity and the completion times need to be appropriately re-calibrated.

Table 5.9: Design changes made to address the sub-themes *Credibility* and *Usefulness of Suggestions* in *SmartDrive 2.0*

Sub-theme	**Design Edit**	**Rationale**
Perceived Credibility	Links to abstracts of relevant studies	Screenshots of publicly available abstracts of studies showing correlations to the specific task were added in the scores screen. This was to encourage the user to pursue the scientific validity of the test, but also add appropriate credibility to the tests as well.
	Task metric explanations	A separate screen explaining the metric used in the test, the average expected score and the cognitive aspect most pertinent to driving is presented in addition to the overall scores to help the user associate the tests to on-road driving.
Usefulness of Suggestions	Option to select and record suggestions	To avoid passive perusal of the suggestions and to promote active thinking, option to select and record suitable suggestions is provided in every suggestion screen. The session package that is emailed to the user after the app-use would include these selected suggestions to help remind them of their driving plan and next-steps.

5.5 Phase-2 Participants

Phase-2 interviews had a total of eight participants. Half (n=4) participants were randomly selected from the 13 participants in Phase-1 who expressed their interest to participate in Phase-2 of the study. This was to evaluate the modifications made in *SmartDrive 2.0*. The eligibility criterion for these participants was only that they had previously participated in the Phase-1 assessment of the prototype. This was to evaluate the design modifications that were made since changes would be more apparent to participants who had interacted with the prototype before.
The other half of the participants (n = 4) were active drivers living with dementia who were recruited from responses to a digital flyer (See Appendix M) disseminated through Dementia Advocacy Canada. Due to the initial struggles in recruitment, the age criterion for those with dementia was lowered to 60 years while the rest of the criteria were kept the same, namely:

- Be 60 years old or older
- Hold or have held a valid driver's license
- Be actively driving or have stopped driving within the past six months.
- Have a minimum of 10 years of driving experience
- Be able to provide informed consent
- Be able to communicate fluently in English item Should own and be able to use a tablet with a functional touch screen.
- Are diagnosed with mild cognitive impairment or dementia

5.6 Phase-2: Interview Procedure and Questions

The flow of Phase-2 can be seen in Fig. 1.1 and the interview procedure was identical to the one used in Phase-1 study for the newly recruited participants driving with dementia. The questions asked for the repeat participants were focused on the design modifications and their opinions on the *SmartDrive 2.0* version compared to the *SmartDrive 1.0*,

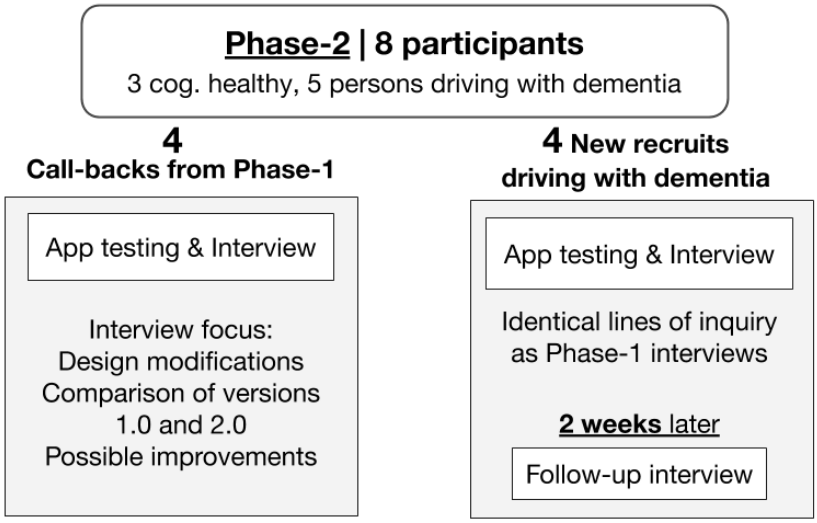

Figure 5.7: Participant characteristics and interview guides/questions used for the Phase-2 study.

both of which they had experienced. The new participants driving with dementia were asked questions identical to the ones in the Phase-1 guide (See Appendix G since it was a first-time experience for this group.

5.7 Phase-2: Data Analysis

Cognitive walkthroughs and the interviews of all eight participants were transcribed verbatim by three researchers (led by the author). Three researchers individually coded two transcripts each and identified any and all codes that emerged. All 174 codes were gathered, discussed and edited to establish context. Similar codes were grouped and those deemed irrelevant to the research questions were discarded. To confirm data saturation, each researcher coded one transcript each; no new codes were identified. After this, a consensus for the final list of codes was reached. The primary researcher (i.e., the author) coded all eight transcripts using the common list of codes. Any new codes identified was discussed by the research team were re-grouped or added to the list as deemed

fit.
The 10 minute follow-up interviews were coded by the author alone as this was a simpler interview that had Yes/No questions inquiring changes in driving habits and/or reasons for inaction as a result of the experience with *SmartDrive 2.0*.

5.7.1 Demographics, Scores & Survey Responses

A total of eight participants were recruited, five of whom self-reported a diagnosis of dementia (See Table 5.11 for details). The demographics and driving status are listed in Table 5.10 below. The scores received by the participants in all three tasks are listed in the Table 5.12 and their responses in the surveys evaluating the three aspects: usability, usefulness and design of *SmartDrive 2.0* have been recorded in the Table 5.13.

Table 5.10: Demographics and driving experience of Phase-2 participants (n=8).

P.Code	**Age (yrs.)**	**Gender**	**Driver**	**Driving Experience (yrs.)**
P1*	73	Male	Occasional	58
P2	80	Male	Primary	64
P3	62	Male	Primary	44
P4	61	Female	Occasional	37
P5*	75	Male	Primary	54
P6*	68	Male	Occasional	52
P7*	82	Male	Primary	64
P8	60	Male	Occasional	42
Average	70.12	–	–	51.88
Std. Dev.	8.12	–	–	9.46

* indicates participants who also completed Phase-1.

Figure 5.8: Scores of the four participants in all three tasks compared in Phase-1 and Phase-2 of the app testing sessions. Yellow indicates and improvement in scores and blue indicates reduction in score and performance. P1 and P2 used desktops with mouse and keyboard while the rest used tablets with touch screens.

P. Code	Mazes Completion time (seconds)		TMTb completion time (seconds)		UFoV shortest display time (milliseconds)	
	Phase-1	Phase-2	Phase-1	Phase-2	Phase-1	Phase-2
P1*	15	12.2	116	144	533	616
P5	6	6.5	84	69	516	66
P6	7	7.8	39	37	116	17
P7	n/a	16.5	89	75	183	616
Avg.	9.33	10.75	82	81.25	337	328
SD	4.03	3.93	27.65	39	189	287

Table 5.11: Years since diagnosis for those older adults living with dementia who participated in Phase-2 study (n=5).

P.Code	**Type of Dementia**	**Number of years since Diagnosis**
P1	Mixed	1.5
P2	Mild Cognitive Impairment	4
P3	Alzheimer's Dementia	5
P4	Early onset Alzheimer's with Lewy Body, and possible vascular dementia	28
P8	Young onset dementia probable Alzheimer's	3.5
Average	—	8.4

Table 5.12: Scores in the tasks and the self-rating scale of participants in Phase-2 interviews (n=8). * indicated Phase-1 repeat participants

P.Code	**Mazes** (seconds)	**TMTb1** (seconds)	**TMTb2** (seconds)	**UFoV** (milliseconds)	**Self-Rating**
Desktop					
P1*	12.2	144	82	616	Caution
P2	18.7	146.8	n/a	633	Go
Tablet					
P3	12.3)	158.4	n/a	34	Go
P4	4.7	58.2	n/a	316	Go
P5*	6.5	69	n/a	66	Caution
P6*	7.8	56	37	17	Caution
P7*	16.5	74.6	n/a	616	Go
P8	6.6	n/a	50.9	50	Caution
Average	10.66	101.0	56.6	293.5	—
Std. Dev.	4.76	42.7	18.8	268.9	—

Table 5.13: Participants Phase-2 Usability and Usefulness Ratings (n=8).

P.Code	**Perceived Usefulness**		Perceived Usability		Interface Design	
	Score	Useful	Score	Usable	Score	Design
P1	79	Agree	64	Agree	50	Agree
P2	75	Agree	48	Neutral	86	Agree
P3	86	Agree	83	Agree	86	Agree
P4	97	Agree	92	Agree	100	Agree
P5	65	Agree	86	Agree	71	Agree
P6	75	Neutral	85	Neutral	90	Agree
P7	86	Agree	39	Disagree	36	Neutral
P8	90	Agree	81	Agree	61	Agree
Avg Score	81.2	—	72.3	—	72.5	

*A score of 100 indicates strong agreement to all positive statements and strong disagreement to all negative statements about the interface.

5.8 Phase-2 Emergent Themes

Identical to the previous method of analysis in Phase-1 (See Section 5.2: Phase-1 Data Analysis), three researchers independently coded two transcripts each (one transcript corresponding to a call-back participant from Phase-1 interviews and one new recruit, person driving with dementia). Using Phase-1 themes as a guide, any new codes or themes identified were discussed and categorised appropriately. To ensure data saturation, another transcript each was individually coded by the three researchers. While a significant overlap in themes was observed between Phase-1 themes, a few new sub-themes were also identified.

As mentioned previously in the Section 5.6, to avoid repetition of identical lines of inquiry that were made in Phase-1 interviews, the call-back participants were only asked their opinions about design modifications in SmartDrive 2.0. Since only the newly recruited participants discussed the rationale for application-use and other factors influencing it, total number of participants for many of the tables below is four (i.e., the new participants to the *SmartDrive* study).

Most themes that emerged in Phase-2 were identical to the previously identified themes and sub-themes shown in Phase-1 (See Tables 5.4, 5.5, 5.6)

All the themes that emerged in the analysis of Phase-2 interviews have been listed below (See Tables 5.14, 5.15, 5.16). New themes that emerged have been highlighted in magenta and illustrated with a representative quote.

Part 1. User/Individual

The rationale and explanations for this part have been mentioned in Section 5.2.2 (Phase-1 Emergent Themes). Only the new prevalence values observed in Phase-2 interviews and the novel themes that emerged have been expanded in this section.

While a subset of the themes identified in Part 1 (See Table 5.4) have repeated in Phase-2 interviews, one new theme emerged (highlighted in magenta in Table 5.14) and has been explained below:

Theme	**Sub-theme** (Prevalence; n-total = 4)
A. **User Needs**	Monitoring driving or cognitive abilities (4) Maintain Autonomy (3) **Freedom of self-assessment** (3)
B. **User Perceptions**	Self-perceived Driving Ability (4) Awareness of Ability Decline (4) Importance of Early Planning (4) Perceived App Purpose (2+)

Table 5.14: List of themes and sub-themes that emerged in Phase-2 analysis under the first category identified: User OR Individual, the new sub-themes have been highlighted in magenta

1. **Freedom of Self-assessment**
   Three of the four participants living with dementia and actively driving stated that one of the reasons they would use the *SmartDrive* application was because it did not report the results to their doctor. Two participants shared their concern about physicians not being sensitive or aware of how dementia affects driving and that they would immediately report to the MTO asking it to revoke their driver's licenses. Hence, this form a self-assessment and the choices/freedom that it accompanies was mentioned as a crucial design aspect to avoid unnecessary suspension of licenses while keeping informed of changes in driving abilities due to dementia.

P8: *"If they [family physicians] are not sensitised to understand dementia, they would automatically pull your license because they think you're incapable...As soon as you talk about it, they try and pull the license to err on the side of caution. Some of my friends, once they were diagnosed with frontal lobe dementia, their license was pulled right off the get-go. Part of the stigma is 'people who are diagnosed, shouldn't drive'. I advocate that it should be based on ability."*

Part2. App or Technology

A significant number of themes and sub-themes that had emerged previously from Phase-1 analysis (See Table 5.5) for the second part of the FITT model (App or Technology) were observed to repeat in Phase-2 analysis when evaluating the different aspects of the application. Similar to the previous part, only new participants were asked in detail about the different aspects of the application while the interviews for the call-back participants from Phase-1 interviews focused only on design modifications. Hence the total number of participants in Table 5.15 is four; all of whom are driving with dementia (See Fig. 5.7)

Table 5.15: Themes and sub-themes that emerged in Phase-2 analysis under the *App or Technology* category (n=4).

Theme	**Sub-theme**	Positive	Negative	Neutral
A. Usability	Colour & Contrast	2	2	-
	Layout and Navigation	2	1	1
B. Accessibility	Type of device	1	3	-
C. Tasks	Instructions	2	2	-
	Engagement	3	1	-
	Reflect cognitive changes	2	2	-
	Task Randomisation	-	2	2
D. Feedback	Presentation Style	2	1	1
	Encouraging Tone	-	2	2
	Usefulness of recommendations	3	1	-
	Improved understanding of skills	3	1	-

As shown in Table 5.15, there was a mixed reception about the different aspects of the *SmartDrive* application. Two participants mentioned that the colours were dull and could be brightened while two preferred neutral tones used. While one participant mentioned that they were comfortable using a tablet, three stated that they would prefer

using the application on a laptop or desktop. Two participants were able to navigate through all the three task instructions, practice sessions and task screens without any explanation from the author during the interview, but two participants struggled to comprehend the UFoV task instructions. One did not opt to re-do the task while the fourth participant re-did the task after repeating the practice session and performed significantly better.

Three of the four participants found the tasks (especially mazes) engaging while one participant mentioned that the UFoV task was unclear and challenging. Two participants stated that the tasks were capable of reflecting changes in their cognition (those that would affect driving) as they age and the dementia progresses. The other two participants mentioned that they did not think this would occur due to the possibility of over-familiarity of the task it it were repeated too often. The next sub-theme, *task randomisation*, captured their concerns regarding the need to randomise the task design every time the user logs in to perform them.
Two participants liked the presentation style of the feedback stating that the information (both performance labels and score values) was clearly presented and the scores to summary screen sequence was easy to navigate. One participant mentioned that the labels used can be more definitive since they were not clear what constitutes an acceptable performance and stated this led to confusion about identifying the appropriate next-steps.

- **Encouraging Tone**
  This was a new sub-theme that had not emerged in the previous analysis of Phase-1 interviews (See Table 5.5). It reflects the kind of tone that suggested recommendations should have. Two of the four participants mentioned that encouraging language should be used when recommending driving adjustments. They stated that older adults driving with dementia need to be reassured that driving adjustments should not be embarrassing to them, rather they should be positioned as necessary strategies to improve safety on the road.

  P3: *"You need to paint a picture...I often avoid driving in the night, I am changing some driving habits. 'There is no shame in adjustments in driving' comments like that in the app [should be added]."*

Three participants found the recommendations to be useful, they stated that most of the suggestions were familiar to them and were already considered by them in their 'driving plan', but made for an effective refresher for possible next-steps. One participant mentioned that the list of recommendations should be personalised to each user's performance and scores instead of presenting a general list and that this is especially important for scores that were critically below average or lower since those who scored very low might not be safe on the road and this should be explicitly informed to the user. Three participants mentioned that the scores from their performance in tasks increased their understanding of their skills (cognitive and driving). They stated that they were not aware of the weaknesses in specific cognitive functions that *SmartDrive 2.0* had presented to them. One participant mentioned that they did not find the scores relevant to driving and had not acquired any new knowledge about their skills.

To separately evaluate the effectiveness of the design modifications made to *SmartDrive 2.0*, two data categories were analysed from the interviews of the call-back participants: (1) the reception (positive or negative) of the design changes made, and (2) overall change in experience of the application for second-time users by comparing both versions of *SmartDrive* (1.0 & 2.0). The author's findings are presented below:

- **Reception of Design Changes** For each of the design modifications explained below, please refer to the table number listed adjacent to the item for more details about the changes.

    1. **Task instructions (See Table 5.8)**:
    one in four participants noticed and positively commented on the 'Start' and 'Finish' prompts that were added to each of the maze, they stated that it helped compensate for the partially blocked view due to the finger being placed on the dot to drag it between the maze walls. The other three participants did not notice these prompts.
    Two participants stated that the change to step-wise instructions with images of screenshots of different task stages helped them to understand the task better. Both participants repeated the practice session (another design change made in version 2.0). There were also significant improvement of scores in the UFoV task for both participants (Phase-1 time in milliseconds: 116, 516 improved to Phase-2: 17, 66 respectively.) (See Fig. 5.8).

However, two participants had difficulty in comprehending the task instructions. Additional explanations from the author in the interview did not affect their scores, neither opted to repeat the practice session. It is important to note that one of the participants mentioned issues they were experiencing with their eyesight and had an appointment scheduled with their optometrist in the same week. The other participant was able to perform significantly better in the task when they repeated it out of curiosity after the interview ended (Phase-1 time in milliseconds: 183, 533 reduced to Phase-2 time in milliseconds: 616, 616 respectively)(See Fig. 5.8)

2. **Links to abstracts of relevant studies (See Table 5.9)**
   One of the four participants stated that having an option to read the abstracts of the relevant studies had improved their perceived credibility of the overall application but the other three participants mentioned that it did not affect their perception of application in any manner.
3. **Explanation about task metrics (See Table 5.9)**
   Another participant mentioned that having additional information about the studies correlating the tasks to on-road driving while processing their own scores and performance was helpful in understanding the correlation between the task and driving; three participants did not notice or comment about this change.
4. **Options to select and record suggestions (See Table 5.9)**
   Three participants stated that they liked the feature of recording the selected options in the list of recommendations that are presented to them. One participant mentioned they felt this made the process more complex than needed. All four participants clicked on the option to send themselves the session package (that includes score, selected suggestions and the driving plan that they created in the application.)

- **Second-Time App Experience** When asked for preference between version 1.0 and 2.0, all four participants stated that they had a better experience with version 2.0. One participant mentioned that they found the layout simpler without having to click on too many buttons. Two participants mentioned that they were more

comfortable with the application since they had performed the tasks once before and knew what to expect.

Part3. App Effects

A significant overlap was observed between the themes and sub-themes that had emerged under the FITT Part 3 category, *App Effects* (See Fig. 5.3), and those observed in Phase-1 analysis (See Fig. 5.6). The follow-up activities that were not considered and have been highlighted in gray while new activities that were previously disregarded and were considered by participants in Phase-2 are highlighted in magenta. Since all the eight participants were asked about the perceived credibility of the tasks and scores they received (deductive, pre-defined codes uniformly inquired about to all eight participants), the n-total for these lines of inquiries are 8. Similarly all eight participants were asked what their next-steps would be after viewing their scores and their responses have been recorded in Table 5.16 below.

As seen in Table 5.16, four participants stated that they were surprised by the scores they had received. One participant mentioned that they were positively surprised, stating that they received scores higher than they had expected while three of the four participants stated that they received scores lower than they had expected. The other four participants stated that they were not surprised by their results and correctly estimated their scores within the application as well.
Five participants accepted that the scores were true indication of their cognitive skills while three disagreed with the premise that the scores reflected their skills. Seven of the eight participants mentioned that they perceived strong correlations of the tasks to on-road driving. All 4 call-backs from Phase-1 had already agreed to this correlation in Phase-1 interviews as well and this is reflected in Table 5.6.

Four participants positively remarked that the would consider planning for their driving future and this was noted as a direct result from their experience with *Smart-Drive 2.0*. Three of the newly recruited participants (driving with dementia) mentioned that they already had a driving plan and that this application would make a good addition to it. Two participants living with dementia mentioned that the app prompted

them to consider brain training exercises while the other two stated that they were already pursuing this option. None of the call-backs mentioned positive or negative comments about this option. All of the eight participants stated that they did not need to connect with physician or a driving instructor, this option was deemed unnecessary and premature by all. Seven of the eight participants (87.5%), which included three of the four newly recruited participants, wanted to use the application again. All seven mentioned that they would like to monitor their scores periodically to observe any changes in their cognitive skills. One participant mentioned that the app prompted them to think about alternative transportation. This participant had received lower scores in UFoV in Phase-1 and Phase-2 app testing sessions and had scheduled an appointment with the optometrist. They also mentioned that they had identified public transit options in their neighbourhood to use.

Table 5.16: Themes and sub-themes that emerged in Phase-2 analysis under the third FITT category, *App Effects*. New sub-themes have been highlighted in magenta and old sub-themes that were not considered are in gray.

Theme	**Sub-theme**	Positive	Negative	Neutral
Perceived Credibility	Results Dissonance	4	4	-
	Acceptance of Results	5	3	-
	Relevance to Driving	7	1	-
Follow-up activities	Explore a Driving Plan	4	-	4
	Explore Cognitive Exercises	2	-	6
	Connect with Professionals	0	8	-
	Revisit Application	7	1	-
	Alternative Transportation	1	7	-
	Discussion with family or friends	-	-	8
	Take a Driving Course	-	-	8
	Increase alertness in car	-	-	8

5.9 Analysis of Phase-2 Follow-up Interviews

As was done in the pilot study (See Table 4.7) and in Phase-1 study (See Table 5.7), the impact of the application on the driving behaviour of the participants was gauged through follow up interviews two weeks after the Phase-2 prototype exploration. All 4 newly recruited participants were called back exactly two weeks following the study. Similar (percentages) to the observations from the pilot and Phase-1 follow-up interviews, three participants discussed the application or driving with someone in their social circle. All four participants mentioned that they already had a driving plan that was made in in collaboration with family and physicians and 3 stated that the application would make a great addition to their plans. Only 1 participant stated that the experience with the application impacted their in-car driving habits, they mentioned an increase of awareness of surrounding objects while driving. Three participants mentioned that the application reassured them of their driving skills (1 participant (See Table 5.12, P8) scored average and above in all tasks and the other two (See Table 5.12 P3 & P4) scored average and above in 2 tasks and slightly below average in 1 task).

Table 5.17: Follow-up interview responses of the participants (living with dementia, new recruits) who were called back two weeks post their Phase-2 interviews (n=4).

Possible Action Plans	Positive reactions (n-max: 4)	Negative reactions (n-max: 4)
Discussion about application or driving	3	1
Add app to existing plan	3	1
Self-introspection about their driving	2	2
Impact of app on driving	1	3
Reassurance about driving	3	1
Willing to repeat app-use	3	1

5.10 Chapter Summary

This chapter introduced the testing protocols used for both Phases (1 & 2) of the usability study to evaluate *SmartDrive*. 16 older adults (average age: 74.3 years, all actively driving) were recruited and interviewed for Phase-1 using the questions guided by the Technology Acceptance Model [27] to examine the perceived usefulness and usability of *SmartDrive 1.0* and *SmartDrive 2.0* versions. Phase-1 analysis revealed overarching themes falling under three categories that were identified through the FITT model [4]. The modifications that were made to *SmartDrive 1.0* based on Phase-1 analysis and discussions with the co-developer were explained. The key changes made were:

- Sub-theme: Perceived Credibility.
  Design Change: Explanations about the task, skills and screenshots of abstracts of relevant studies during score presentations.
- Sub-theme: Usefulness of Suggestions.
  Design Change: Radio buttons so the user can select and record suggestions that they would consider (safer driving habits, chat with a physician etc.) instead of passive reading of text.
- Sub-theme: Instructions.
  Design Change: Step-wise instructions for UFoV and multiple practice sessions so the user can proceed to the task without any confusion about the procedure.

The modified version i.e., *SmartDrive 2.0* was further evaluated with eight participants (four callbacks Phase-1 and four newly recruited participants driving with dementia, average age: 70.1 years). The new themes emerged from the thematic analysis of Phase-2 interviews were: (1) Freedom of Self-assessment, (2) Encouraging Tone and (3) Alternative Transportation. These were particularly emphasised by those living with dementia. The usefulness scores were observed to increase by 7% from *SmartDrive 1.0* to *SmartDrive 2.0*. Usability and design scores saw a combined increase of 12% from *SmartDrive 1.0* to *SmartDrive 2.0*. The analysis of the follow-up interviews revealed an overall positive impact of app on the participants' driving habits. 15 of 19 participants wanted to use the app again to monitor their scores and changes in cognitive skills so they could

independently self-regulate or stop driving in the event of declining scores. 11 of 19 participants mentioned a range of effects of their experience with the app: (1) two stopped driving and scheduled appointments with their optometrists, (2) 10 participants mentioned increased alertness while driving and (3) 10 participants stated that *SmartDrive* prompted them to explore an early driving plan for their driving futures.

The results from this research suggest that a majority of the older adults are positively receptive to a driving self-assessment app such as *SmartDrive* and perceive it to be useful and usable in prompting early planning for driving cessation and promoting safer driving habits.

Chapter 6

Overall Discussion

6.1 Research Findings

To position the significance of the findings of this thesis research, it helps to recall the guiding research questions and their related studies, and key outcomes, which are:

- **Q1**: How do older adult drivers perceive a driving self-assessment application?
  Study: Pilot Study with exploratory interviews.
  Key outcomes: Identified five major overarching themes related to app design and functionality that were used to improve the design of subsequent versions.

- **Q2**. How useful and usable is the co-developed application?
  Study: Phase-1 & Phase-2 of Main Study with iterative design testing.
  Key outcomes: Expanded on overarching themes identified in the pilot study and a framework for categorising those themes resulted in an app that participants rated with good usefulness and usability.

- **Q3**. How can the application prompt early planning for driving cessation?
  Study: Follow-up Interviews two weeks post interview session that probed any observed changes made by participants to their driving habits.
  Key outcomes: Analysed the effectiveness of the app in making changes to participants' perceptions of driving (including intent to explore a driving plan). Par-

ticipants noted a positive impact on driving habits (increased alertness in car due to lower scores in app, avoiding busy intersections and rush-hour traffic, appointments with optometrist to re-assess their vision) and a high prevalence for intent to repeat use of app was recorded.

The pilot study data helped us gain initial insight as to how older adults might perceive the idea of a driving self-assessment. Most of the themes and sub-themes identified in the pilot have been recognised in similar app-assessment studies. For example, the importance of *Awareness* and *Motivations for Use* have been observed in evaluations of other driving interventions for older adults [16] [17], although these were from a clinician's perspective. The notion of *Trustworthiness* has been explored before in fitness apps to understand willingness to use [15], however, the sub-themes listed here are more specific and relevant to a driving self-assessment application and (to the author's knowledge) are novel propositions from this research. All of the sub-themes identified in the *Action Plan* and *Follow-up activities* have been advertised in previous driving tool-kits [20], no differences were found. But a few, more prevalent activities were recorded as natural next-steps that older adults would take as part of their driving career. The observations of the more prevalent options and their feasibility could potentially help update tool-kits or in the design of other driving guides.

Overall, four of the six participants in the pilot study were enthusiastic about using the application again especially to periodically monitor their scores to observe any changes in their cognitive skills. Despite the small size of the sample, this was positive evidence that there is interest in an application like *SmartDrive*. The themes from our pilot study not only helped in observing new patterns in application-use but identified limitations of the initial version of the prototype that were addressed through appropriate design modifications in subsequent versions (*SmartDrive 1.0 and 2.0*).

As can be seen from Tables 5.3 and 5.13, the usability and usefulness of the subsequent versions increased from Phase-1; Usefulness Avg: 74.5/100, Usability Avg: 64.9/100, Design Avg: 67.8/100) to Phase-2; Usefulness Avg: 81.2/100 Usability Avg: 72.3/100, Design Avg: 72.5/100). Since impressions and feedback improved from the pilot interviews, this indicates the successful implementation of iterative and co-development practices when developing *SmartDrive*.
The impact of individual design changes cannot be identified, however, this improvement

in user perceptions can be attributed to several factors: (1) incorporating step-wise instructions for all tasks and allowing multiple practice sessions to ensure that user proceeds to the task without confusion (2) Adding explanations for task correlation to on-road driving at multiple stages of the application to establish a stronger context, (3) Providing the option to actively interact (clicking on boxes that apply) with the suggestions presented to the user instead of a passive reading approach and (4) allowing the freedom of choice to the user to select the suggestions that would suit their unique situation in life and abilities.

The highest percent increase observed was the effect of planning prompts in the application as observed in the follow-up interview responses in phases 1 and 2. Compared to the 46% in Phase-1, 75% of the participants in Phase-2 mentioned that they would explore a driving plan. The change in presentation from ambiguous questions to specific prompts so the user can think critically about the possibility of scoring less than they expected could have likely caused the increase. However, it is also important to note that all four of the participants in Phase-2 follow-up interviews were those from the dementia cohort. Participants living with dementia have a higher propensity to have begun early planning on the account of their diagnosis, their knowledge of cognitive decline and frequent interactions with their physician. This was one of the key findings from the comparison of both cognitively healthy and dementia cohorts. Since those living with dementia were frequently exposed to cognitive tests, it is likely this made them more receptive to the idea of task correlations to on-road driving and benefits of advance planning for driving cessation.

6.1.1 Possible Misuse

As has been discussed in Section 3.1, physicians use many online applications such as DriveABLE, CogniFit, etc. [31], [18] in conjunction to their individual screening processes for driving fitness. While *SmartDrive* might have the potential to become an application that can aid physicians or transportation authorities, the objective of it remains as a self-administered, independent and private exploration into one's driving-related cognitive ability. This was the gap in literature that was identified and *SmartDrive* sought to address. The system usefulness questionnaire, which inquired if *Smart-*

Drive would make it easier to approach the subject of their driving with physicians, received high scores (74.5 in Phase-1 and 81.2 in Phase-2). This indicates that older adult drivers perceive this application useful and supportive in engaging in conversation with their physician, although validation of *SmartDrive* with gold-standard measures (e.g., on-road performance, pen and paper tests, etc.) would need to be done with a larger population over longer periods of time before it could be made available for use.

There are potential risks of possible misuse that would need to be considered and addressed for widespread use of *SmartDrive*. While the following scenarios did not emerge in the analysis of our data, they are examples of aspects that must be considered and addressed in real-world use:

- **Scenario**: Substituting app with visits to the physician
  Older adults might rely on the *SmartDrive* and either completely substitute their regular visits to their physician for a driving check-up or reduce the overall frequency of visits. Neither of these are intended effects of the design and hence have been classified as misuse. This substitution can inadvertently cause an increased crash-risk since medical practitioners would be best equipped at screening for driving fitness.
  Recommendation: *SmartDrive* can include, in its introductory screens, details about the way to use the application in addition to physician visits, information about the context of use can be provided to the user. Transparency about limitations of the app would also allow the user to compensate for them through visits to their physician.

- **Scenario**: Receiving contradictory information
  Older adults might receive good scores on *SmartDrive* while their physician observes a decline in skills or visa-versa. It is also possible that the user's skills have declined but this is not reflected in *SmartDrive*'s scores if the user has repeated the tasks too frequently and are now overly familiar with the activity (i.e., they have higher performance through familiarity and training). Both these situations would lead to a misrepresentation of their true skills and might cause the user to disregard physician advice regarding a need for driving cessation.
  Recommendation: *SmartDrive* should include disclaimers about possible inac-

curacies in single-time testing and recommended frequency of use to promote correct use of *SmartDrive* and help avoid the user misinterpreting the suggestions or over-use the application. Similar to the above, being transparent about limitations could motivate the user to discuss their scores with their physician to clearly understand the meaning of the scores.

- **Scenario**: Dismissing application's suggestions.
  In the current design, the user is presented a list of options, each addressing a different severity level, without being explicitly directed to any one in particular (e.g. brain training, optometrist, driving school etc.). The user can choose to ignore all suggestions, might even opt a less safe but more convenient option which is an unintended effect of the feature that is aiming for flexibility and independence.
  Recommendation: This issue is harder to address because surveiling and enforcing safe habits is inherently contradictory to the fundamental objective of a private, independent self-assessment where results are not shared with any other agency. One way to approach this would be to provide the user with the potential risks involved in dismissing a suitable option for their performance level. Providing an unbiased crash statistics would allow the user to quantify their safety. This can only be done after the app is validated through on-road testing with a large population.

All these situations of possible misuse need to be addressed in the subsequent versions of *SmartDrive* to minimise negative potential consequences as a result of the adoption of the application.

6.2 Implications for Task Design

6.2.1 Tasks: Number & Duration

In Phase-1 interviews, seven participants responded that three was a sufficient number of tasks and that there was no need to expand the application since it would take longer to complete. Eight participants took a 'more the merrier' approach and stated that more

tasks (measuring different cognitive aspects) would help them gain a bigger picture of their driving. This inclusion of several different cognitive tests has generally been found to improve predictability of on-road driving in other studies. A combined analysis of scores from several cognitive tests have observed to yield better accuracy in classification of at-risk drivers [6], [89]. This is an aspect that can be addressed in the future while allowing for user's choice, which could be a significant feature for update and continued use. Perhaps, a few tasks can be made optional beyond the minimum mandatory set that need to be completed.

In both versions of *SmartDrive*, the wireframe is designed such that the user will not be able to view the results until all three tasks are performed (See Wireframe figures 4.2, 5.4). The completion of all three tasks requires about 20 minutes of interaction with the app which fits the average time preference noted for each session: 20-25 minutes. Therefore additional tasks (which would increase app-duration) could be made optional for the occasional user who would like more information.

6.2.2 Tasks: Frequency & Randomisation

Although over-familiarity was raised and is a valid concern, it wasn't addressed specifically in this research, but certainly is a significant influential aspect to further consider and address. The effect of familiarity was observed to have influenced participant scores the second time around. This was noted in the Phase-2 study with *SmartDrive 2.0* design and the call-back participants. Among the four participants who were called back from Phase-1, three of their scores in **all** the tasks improved. While this is at least in part because of improved app design, familiarity or a better understanding of the instructions could have been an equally contributing factor. To mitigate improvements in performance because of over-familiarity, there is a need to select tests, the designs of which can be randomised to allow periodic use.

In all the **Porteus Mazes**, identical paths were maintained across the different versions of the application for the study but this could be modified in the future to present a different path every time the user logs in.

The effect of familiarity in the **TMTb** test can be observed clearly in the difference in Phase-1 and Phase-2 average completion times for the first and second trial of the task (See Table 5.2 & Table 5.12). In Phase-1 the average time taken to complete the

trail reduced from 83 seconds to 64 and in Phase-2 from 101 seconds to 57 seconds. This drastic change in times could be as a result of the immediate repetition of the task or an increase in understanding of the instructions and alertness of the participant. While this effect of familiarity can be compensated by modifying the test metrics and variables (location of numbers, sequence of number-letter to be joined) each time the participant performs it, the way the digital test has been administered in *SmartDrive* (two consecutive trials) needs to be tested with a much larger population (potentially thousands of people) to calibrate the expected change in completions times between the first and second trials for a safe driver. This would allow a much more accurate representation for the user to compare both the data points (TMTb1 and TMTb2 completion times) with the norm.

The **UFoV** test already has random presentation of images, it has been observed that this test can improve visual skills if done frequently and has good potential for a training exercise [69]. Although this indicates that UFoV scores are likely to improve over time as an effect of potential improvement in central and peripheral vision, the possible over-familiarity caused by repeating the test more than the recommended frequency needs to be explored further. It is certainly crucial to address over-familiarity and frequency for Mazes and TMTb tests where there are no implicit randomised test elements. UFoV was perceived as the most challenging task by many in the first phase of the interviews and this was more an issue with the way instructions were presented, rather than the test design. Since it has the highest correlations with on-road driving when compared to the other cognitive tests, UFoV should be implemented in future versions albeit with clearer instructions.

On average, participants from Phase-1 interviews stated that they would prefer to use the application less often than once in 3 months but more than once a year. All the participants in Phase-2 who were living with dementia mentioned that they would like to use the app at least once a month if not more. This was an interesting difference as it is likely related to an awareness of the decline in cognitive skills that occurs with dementia and that drivers with dementia likely want to mitigate risk. It is a good start to gauging how often user's on average would be willing to interact with such an app, which can support other design choices, such as the design and number of tasks, duration of each session, etc.

6.2.3 Usability of the Interface

Tables 5.3 and 5.13 observe a 12% increase in both the perceived usability and design scores combined. This improvement can be predominantly attributed to the three aspects listed below, which were a result of the iterative interface development and testing of the application:

1. **Readability of instructions**:
   As mentioned earlier in Section 5.2, 11 of the 16 participants in Phase-1 required explanations beyond those presented on the screen for the UFoV task. This was addressed in the later version. Only 1 person among the 4 new participants in Phase-2 required additional explanation during the app-testing session. This improved understanding can be attributed to modified layout incorporating step-wise instructions with sequential presentation unlike the previous design in *SmartDrive 1.0* where all the information was presented at once using multiple paragraphs without figures. Adding screenshots of the images that would be presented in the task was observed to improve the user's understanding of the task. Additionally, allowing the option for multiple practice sessions helped eliminate any confusion about the sequence of stimulus presented on the screen. Six of the eight participants chose to repeat the practice session for the UFoV task. Studies have observed that repeating UFoV actually helps older adults in improving their attention and speed of processing [35]. This task has shown potential as a training exercise for improving general cognitive skills [38]. This indicates that for those tasks where repetition would not cause over-familiarity, the option to revisit practice sessions can be implemented for improved comprehension of the activity involved.

2. **Simpler navigation**
   All versions of this application incorporated a unidirectional flow with minimal options for navigation. Although this can restrict choice, it did allow the user to easily proceed through each screen without confusion. This feature was more vigorously implemented in the final version where the scores and suggestions were presented one after the other instead of the previous design where multiple options were shown on one screen and the user could jump in and out of task scores, expla-

nations and suggestion. This allowed a smoother transition between score, explanation of the metrics and final suggestions.
The number of screens were reduced in the final version and the information was re-distributed according to the suggestions received in Phase-1, namely: (1) Participants generally preferred all task scores presented on one screen with options to expand on each task, and (2) A button to revisit *SmartDrive*'s suggestions was added on the screen with the prompt for planning, this allowed the user with one click to re-consider possible options before exploring a plan.

3. **Intuitive layout**
   Compared to the Phase-1 cognitive walkthroughs, new participants in Phase-2 required fewer instructions to navigate the layout within a screen. The final version included several one-line instructions that did not occupy much space but delivered the message as to how to proceed adjacent to the buttons themselves. In the first version (*SmartDrive 1.0*), multiple buttons were labelled according to their functionality relating to the screen that proceeded them ('*SmartDrive*'s Suggestions', 'Go to next maze', 'Pause and Plan' etc.). The second version applied a more uniform and intuitive label across the screens wherever appropriate to avoid confusion. Labels such as 'Continue', 'Next' and 'Begin Task' were used without specifics along with the one-line instructions about the succeeding screen. This allowed for a smoother transition since participants did not have to comprehend the label itself but rather proceed to the next screen by clicking on 'Continue' or 'Next'. Consistency in the button's locations, colours and labels allowed the users to become more familiar and confident as they progressed through each screen.

6.2.4 Usefulness of the Feedback

As Table 5.3 shows, 12 of the 16 participants responded 'Agree' when asked if they found the application useful. Among the four who responded 'Neutral', two participants received lower than expected scores and the others did not agree with the premise; cognitive tests have correlations with on-road driving. These two factors were identified as major barriers in adopting this application. The former speaks to dissonance in expectation vs reality: if there was significant mismatch between the user's self-perceived driving

ability prior to the interaction and the final results, it was less likely they accepted their scored and found the app useful. Secondly, if the notion of cognitive screening for driving ability was not recognised as valid, the person was less likely to use the application and deem it useful. While these findings cannot be generalised, they are novel findings that might help better advertise and present other self-assessment applications.
Among the 12 participants who did find it useful, the significant motivation for use (observed in high prevalence in all phases of study, See Table 5.4, Table 4.6) was the need to monitor performance and scores over time and to take appropriate action (adjust or self-regulate their driving habits or identify alternative options etc.) if significant decline in scores were to be observed in the future. This is a key finding that could help align the way the future versions are advertised and presented to the user so they can better support their predominant motivation for use. Two of the 12 participants also wanted to improve their driving and cognitive skills which was beyond the scope of this purely assessment-focused application but certainly brings the 'seeking improvement' attitude to the forefront of the discussion. While this might not apply to some older adults living with dementia due to the nature of the disease, there is still a need for more research into training applications to better support older adults to help them retain their skills and stay safe on the roads and help them preserve their autonomy.

Several participants mentioned that they rely on comments from other passengers or family members, perhaps even minor errors on the road to identify the need for re-evaluating their driving skills. This is not a safe way to assess driving as they might not always have passengers to inform errors they made and those minor incidents can be overlooked by the driver possibly even leading to major crashes. This application as mentioned by several participants can work as an additional guide to understanding driver's safety. This was reflected in the willingness of several (Phase-1: 13 of 16, See Table 5.6 and Phase-2: seven of eight, See Table 5.16) participants in all phases of the study to begin using the application with a primary objective of monitoring any decline in cognitive skills an their safety on the road.
An increase of 7% is observed in perceived usefulness, while the source of this improvement cannot be exactly pinpointed, it can be attributed to the additional explanations and links to abstract references provided for tasks in the summary screens to help establish a connection with on-road driving. An interesting point to note is that the questions in the usefulness survey is developed (See Appendix I) to inquire whether the application

addressed any driving related concerns the participant might have. In Phase-2, those living with dementia had pre-existing concerns as a result of their diagnosis while cognitively healthy participants did not agree with the statement strongly since they did not have any concerns in the first place. The need to critically think about and discuss driving was more prevalent among those driving with dementia and hence this application was perceived as more applicable and useful to them. In comparison, cognitively healthy older adult drivers did not need to think about or frequently discuss their driving with their physicians and would likely find this application relatively less suitable and useful; this difference in user needs very likely contributed to the increase of perceived usefulness scores from Phase-1 to Phase-2.

6.2.5 Impact of Application on Driving

Several participants, seven of 16 in Phase-1 (See Tablet 5.6), four of eight in Phase-2 (See Tablet 5.6) mentioned that the application prompted them to explore a driving plan. Further persuasive features could be added to the design, such as presenting the benefits of advance planning for driving cessation. In comparison, all five of participants who were driving with dementia were aware of early planning and had already discussed it with their families or physicians. Hence there is potential to customise this information to better suit and apply to cognitively healthy older adult drivers. In this way, people can begin to forward-plan earlier and be more aware of what options are available, thus supporting a more gradual, thoughtful, and person-centred transition if it is necessary.

The positive effects from the app that were significantly prevalent in Phase-1 (11 of 16 participants; See Table 5.6) were increased alertness in the car and discussions with family or friends. Both of these are convenient options that decidedly prevent involvement of agencies with the authority to revoke one's driver's license. Only 4 participants were agreeable to the idea of approaching a professional (e.g., driving instructor or optometrist) but none were comfortable discussing their driving with their physician. While a few mentioned that they did not believe their physician to be suitably trained for driving assessment, most were fearful of immediate suspension of license. This fear was highlighted by those driving with dementia in Phase-2 study where none of the participants living with dementia wanted to approach any professional (driving or medical) as they

predicted a lack of understanding and a threat of losing their license (See Table 5.16). The avoidance of open discussions with physicians emphasises the need for awareness and training among general physicians to ensure that necessary conversations leading to safe driving decisions are possible. This also highlights the need of options for people to privately explore and think about their driving abilities.

6.3 Methodical Considerations and Study Limitations

As with any study, there were inherent limitations in the study protocols. All participants except one were residents of Ontario; out of the 24 participants, 11 were female and 13 were male. Although gender was balanced to some extent, it was skewed within phases. Race and ethnicity were not recorded for participants and this would potentially skew the outcomes since different cultures have varying notions about driving and planning. While the sample size was large (24 participants in total) for a qualitative analysis of this type and stage of research, a larger group representing the demographic more accurately would be necessary to confirm the inferences made in this study.
To achieve scientific credibility for prediction of on-road driving performance, the results from the application must be compared with on-road driving tests. Due to limitations in time and resources, this was not performed. A more robust validation process must be done before an application such as *SmartDrive* can be used by the population.

Another significant limitation caused due to time constraints were the calibration of threshold scores for all three tasks, in particular for maze test. Since the previously digitised versions of Porteus' five mazes did not publish relative times but correlations with crash risk, the completion time for all five mazes were recorded for 10 volunteers as part of this research. Most of them were in the 20-30 years age category and not representative of the target user. Extrapolations were made to match the average, below average and critically below average levels, however, as we could not find values in the literature, these values were set as proof-of-concept. Establishing proper threshold values needs to be addressed in future work for all three tests and how these values may differ for use on a tablet as well as a desktop/laptop will need to be considered to ensure that the user

receives accurate results.

Since the focus of *SmartDrive* and this research study was to explore usability, usefulness and trust features that can persuade the idea of monitoring and advance planning, some modifications were made to the original tasks to explore how to make them accessible and approachable in a self-administered digital format. While these design changes appear to support usability and trust, the modified versions of the tasks must be validated with a larger population over long term by comparing their results to gold-standard tests. This is especially true of those that could significantly change the user's performance (e.g. second trial for TMTb test); these need to be critically examined for their correlations with on-road driving performance.

One major factor that influenced the participant's opinions on the application was their frustration with the Zoom app and switching of windows on a small screen tablet. This affected the mood of several of the participants, especially when there were technical issues (e.g., audio or screen-share malfunction). Connectivity issues also negatively affected the participant's overall study experiences possible reflecting in usability ratings. This was not reflective of the way they would have used this in-person or organically online, as there there would only be one app running (i.e., *SmartDrive*) without the need to switch between multiple apps as was required in the study (i.e., Zoom call, Qualtrics survey and *SmartDrive* app). The user would more likely have had an easier time with the tablet running just one app alone.

While participants were told that the purpose of the research was to explore the design of the interface and that *SmartDrive*'s validity has not been examined at different stages of the interview: beginning of the study, as a discussion topic during the interview, and in the feedback letter, it could have been mentioned in the application itself. In screens where the studies that examined the original task were referenced, limitations of the design changes made to the *SmartDrive* versions could be mentioned explicitly. This would allow for a more accurate interpretation of the value of the scores received by the user. This need for transparency of the limitations of *SmartDrive* needs to be addressed in the subsequent versions.

The COVID-19 lock-down restrictions also affected the effective implementation of a few activities mentioned in the follow-up interviews. Three participants mentioned that they would have discussed the results with their physicians or visited an optometrist if not for long wait times due to the pandemic and general inaccessibility of medical ser-

vices. Five participants mentioned that the discussion about the study and their driving would have naturally evolved if they had their usual meet-ups with their friends but they were socially isolating and this was prevented. Several mentioned their driving habits had already significantly changed because of the pandemic. However, no participant mentioned that they had audio or video calls with their friends. Lack of easy discussion may have skewed the impact that the application had on their driving habits.

Chapter 7

Conclusion

7.1 Summary

This research iteratively developed and evaluated *SmartDrive*; an online application for the self-assessment of driving abilities for older adults. Using the TAM [27] and FITT [4] models as guides, the perceived usefulness and the usability of the application were examined and refined through interviews with 24 actively driving older adults, including five who are living with dementia. Thematic analyses of cognitive walkthroughs and semi-structured interviews as well as usability scales were used to assess the different versions of *SmartDrive*. The analyses revealed several sub-themes not only pertaining to the application design but also underlying characteristics of older adults that would influence the adoption of a self-assessment application. These findings can be translated and employed in the development of other self-assessment applications designed to support the well-being of older adults.

7.2 Key Findings

This research uncovered four key findings related to a driving self-assessment application such as *SmartDrive*:

1. **Older adults were open to making adjustments to their driving habits in order to compensate for a change in skills, especially for those skills that they themselves observed to have declined.** The rationale behind these adjustments were two-fold. Firstly, older adults wanted to retain the independence of driving. The threat of losing their license motivated self-monitoring of their abilities as they thought necessary. Secondly, they were significantly inclined to ensure their and other drivers' safety on the road. The idea of being a risk and harming anyone on the road troubled them greatly and they wanted to avoid those scenarios. Understanding this perspective is crucial to the design, uptake, and use of an app to support driving.

2. **Older adults want to observe their driving skills and to monitor the effects of age-related cognitive or even physical decline on their driving safety in a way that supports their autonomy.** The older adults in this research were concerned that engaging in driving evaluations conducted by transportation authorities or third party agencies might simply cause revocation of their licenses unfairly, which supported a need for private and confidential self-assessment.

3. **Older adults are amenable to the idea of cognitive testing as a screening method for gauging driving fitness.** The relatively high acceptance of cognitive testing as a viable method to assess driving abilities was unexpected. 18 of the 24 older adults in this research stated they had a positive experience and were willing to use the application periodically. This suggests older adults felt an app like *SmartDrive* could be an effective way to assess driving abilities and felt it could be a usable and useful tool to support safe decisions.

4. **The significance of advance planning for driving cessation was not popular among the cognitively healthy older adults.** The benefits of early planning were not familiar to cognitive healthy older adults; this was not a common process and was not explored by many older adults. The attitude in general can be very well described by one participant's phrase 'go with the flow'. The need for planning was predominantly influenced by the age criterion that MTO has for relicensing procedures (above 80 years) and if the older adult observed any minor crashes while driving. A more pro-active approach can certainly be implemented

through self-assessment applications that allow for periodic monitoring of driving skills and more autonomy and choice for if and when driving cessation must occur.

The interface design modifications noted and applied in this study can be translated and used in other self-assessment applications and applications for older adults in general, particularly for development of web-based applications. The significantly higher prevalence of certain themes and sub-themes noted can help dictate the points of priority for other designs.

7.3 Future Work

Th study limitations mentioned in the previous chapter need to be addressed in the subsequent versions of this applications. A few are:

- **Establishing Credibility**:
  To ensure validity of the set of tests implemented in the application, the performance in these tests must be compared with on-road driving scores. Currently, the credibility of the application relies on faithful implementation of previously validated cognitive tests but small deviations that cannot be avoided should be addressed through comparisons with on-road driving performance.

- **Liability**:
  One of the important features of the application were open-ended suggestions that did not map to the performance level. The user is presented with a general list of recommendations that they may choose to follow regardless of their performance levels. This can possibly open the application to liability in terms of safety of those drivers who ignore the suggestions. Although this feature was preferred by a majority of the participants, this limitation has to be addressed either through initial disclaimers or communicating the results to the MTO in case of consistent poor performance.

- **Risk of over-familiarity**

Several participants mentioned that they would prefer to assess themselves more than once a month. This can likely cause a false sense of security rooting from good scores on the screen that are not a reflection of good skills but rather over-familiarity with the test. This indicates a need to accommodate frequent use either in the test design or prevent the user from logging in too frequently. Both these options need to be explored in order to ensure that the scores remain valid and accurate for each session.

- **Additional tests**:
  This version has been limited to three tests due to time restrictions, but more tests that have shown correlations with driving can be added in order to acquire an accurate view of one's driving abilities. These tests should not be prone to over-familiarity and should be designed in a manner that is easy to self-administer.

- **Flexibility in device choice**:
  The application for the versions in this study were deployed and accessible only on a tablet. This limitation not only affected our recruitment but was noted by many as a barrier to adopting the application. Around half of the older adults interviewed were more comfortable using a desktop with a mouse and keyboard as opposed to a touch screen. Designing versions that are supported by multiple devices would allow for a more convenient use and a larger user-base.

7.4 Final Remarks

The goal of this thesis research was to create and evaluate a driving self-assessment application that older adults would find useful and actually use. The results suggest that cognitive testing is a viable and acceptable method of driving assessment among most older adults who were interviewed in the study. Many were unfamiliar to the concept of this application, but liked the design and were willing to use the application again to periodically monitor their driving abilities. Although the findings of this research need to be further investigated with a larger cohort with on-road evaluations, there is good indication that an app such as *SmartDrive* would be accepted and used by older adult drivers. The application's overall positive reception was heavily attributed to the use of

participatory design methods which involve the values and preferences of the users to influence the design early on in the development process.
This thesis contributes to the research conducted in the adoption of driving assessment applications for older adults. This work is a step towards understanding the needs of older adults drivers and designing applications that aim to promote safe driving decisions while acknowledging and respecting the autonomy of older adults.

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APPENDICES

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Appendix A

Information Sheets: Pilot, Phase-1 & Phase-2 Studies

Appendix B

Consent Forms: Pilot, Phase-1 & Phase-2 Studies

CONSENT SHEET

Project Title: Prototype testing of a digital interface that enables older adults to self-assess their driving ability

Research team members

Name	Role	Department	E-mail
Jennifer Boger Assistant Professor	Principal Investigator	Systems Design Engineering	jboger@uwaterloo.ca (519) 888-4567 x38328
Surya Sarada Neti MASc student	Student Investigator	Systems Design Engineering	ssneti@uwaterloo.ca

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By agreeing to the options below, you are not waiving your legal rights or releasing the investigator(s) or involved institution(s) from their legal and professional responsibilities.

I have read the information presented in the information letter about a study being conducted by the research team as part of a study conducted by Surya Neti led by Dr. Boger from Systems Design Engineering at the University of Waterloo. I have had the opportunity to ask any questions related to this study, to receive satisfactory answers to my questions, and any additional details I wanted.

- I am aware my information will be de-identified.
- I am aware that my de-identified data will be posted on a database AND/OR made available upon request for research purposes by other researchers.
- I am aware that I may withdraw my study participation at any time without penalty by advising the researcher.

This study has been reviewed and received ethics clearance through the University of Waterloo Research Ethics Committee (ORE **#40677**). If you have questions for the Committee contact the Office of Research Ethics, at 1-519-888-4567 ext. 36005 or ore-ceo@uwaterloo.ca.

☐ I agree to my interview being audio recorded to ensure accurate transcription and analysis.

☐ I agree with the use of anonymous quotations in any thesis or publication that comes from this research.

Data use in future research

Additionally, I consent for data collected in this study to be used in future research. My consent / non-consent to the future use of data does not impact my participation in this Study.

☐ I agree consent for my data to be used in future studies.

Appendix C

Demographics Questionnaire: Pilot, Phase-1 & Phase-2 Studies

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DEMOGRAPHICS & DRIVING HABITS QUESTIONNAIRE

This is a strictly confidential questionnaire. Only a randomly generated participant ID number, assigned by the research administrator will be used on this questionnaire. No information reported by you here will be traced back to you personally in any way. You can skip any questions you do not feel comfortable answering.

Q1. Demographics

Gender: ☐ Male ☐ Female ☐ Other

Age: _____ years

Education: What is the highest degree or level of school you have completed?

_____

At what age did you get your G (i.e., full) driver's license? ____ years old

---

Q2. Driving History

☐ I currently drive

If you are more than 80 years old, have you successfully taken the driving license renewal test?

☐Yes ☐No

In my household…

☐ I'm the primary driver ☐ I'm the driver occasionally

☐ I seldom am the driver

_____

☐ I currently don't drive

If you don't drive anymore, please answer the questions below and leave Q3 blank.

When was the last time you drove? _____ *(MM)/(YYYY)*

Please state the reason you stopped driving

_____

_____

_____

Q3. Approximately how far did you drive in the <u>past week</u>?

☐ Less than 50 km ☐ 50-100 km ☐ 100-200 km

☐ 200-300 km ☐ more than 300 km

B. About how far did you drive in the <u>past 12 months</u>?

☐ Less than 5000 km ☐ 5000 to 10,000 km ☐ 10,001-15,0000 km

☐ 15,001-20,000 km ☐ more than 20,000 km

C. How many years have you actively been driving? _____ years

D. What kind of roads do you mostly drive on (check all that apply)?

☐ Highways ☐ City Streets ☐ Country roads

E. How fast do you usually drive compared to the general flow of traffic? Would you say:

☐ Much faster ☐ Somewhat faster ☐ About the same

☐ Somewhat slower ☐ Much slower

F. Do you adhere to the posted speed limit? Would you say:

☐ Always ☐ Mostly ☐ Sometimes ☐ Rarely

G. Do you often drive in rush hour traffic?

☐ Yes ☐ No

If NO to the above, do you intentionally avoid driving during peak traffic hours?

☐ Yes ☐ No

H. Have you experienced difficulty left hand turns across oncoming traffic?

☐ Yes ☐ No

I. Have you experienced difficulty while driving at night?

☐ Yes ☐ No

J. Have you experienced difficulty when driving alone?

☐ Yes ☐ No

K. Considering your answers above, has your driving style changed over time? If yes, how?

_____

_____

_____

L. Has anyone suggested over the past year that you limit your driving or stop driving?

☐ Yes ☐ No

If yes, please elaborate:

_____

_____

_____

Appendix D

Interview Guide 1: Pilot Study

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SEMI-STRUCTURED **INTERVIEW GUIDE**

Before use of interface

Purpose of the interface:

- An easy to use self-assessment tool that implements a set of cognitive tasks that can provide information about cognitive abilities and can provide information related to risk of drive.
- Provide simple and easy to read feedback that can help the user interpret the outcomes from the tasks they've performed in a way that can support them in thinking about and making changes to their driving IF it is necessary

NOTE: The trail making task implemented in the study has been shown to give a general idea of one's driving ability in previous literature but has not been clinically validated in this application. Whatever feedback you receive through this application has also not been clinically validated, this research is strictly exploratory.

1. What sort of device are you most comfortable with?
    a. Would you like this as an application or a website?
    (how often do you use this device?)
    b. Do you prefer touch or mouse or touchpad?

2. What do you think a tool like this should look like ?
    a. What are the basic features it should include?

    b. What sort of colors and format would you like to see?
    Hint; colors? minimum design or more information?
    Type of apps they like?

    c. What information should a tool like this provide?
        i. Should the feedback from the activities be more obvious or subtle?
        ii. Should there be less text?

iii. How many levels of feedback would you think is best? Good, average, bad or more?

3. When would you use a tool like this?
    a. When you have such and such concerns? Why? Would this information help if you used it during that time?
    b. Time of the day? _____

4. Who do you think should be involved in administering the tool? (Prompt: At the moment, the current design does not require any assistance, is that acceptable?)

5. Whom would you be willing to share this information provided by (results) this tool with?

6. Have you ever been to the doctor's for a driving ability check up?
    a. How was that experience?
    b. How was your experience with the license renewal testing (if applicable)
    c. What were the challenges you faced?

7. What would you like to change about the process? Relicensing, policies?

Appendix E

Interview Guide 2: Pilot Study

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SEMI-STRUCTURED **INTERVIEW GUIDE**

After use of interface

1. How did you feel using the interface?
2. Did you understand the purpose of this interface?
3. Was the activity engaging? Why / why not?
   (informative, useful, helpful)
    a. Was anything hard to follow or understand?
    b. Did you need any more instructions in places and where?
    (Note down for each screen or run through them all)
    c. What did you feel about the tasks themselves? any source of stress needs to be identified
    d. What is your understanding of the importance of these skills in the context of driving? Do you think you'd observe changes in these skills over time?
    e. Would providing difficult variations of this task give you more information?
    f. How much time would you be able to allot for an interface such as this? (on a monthly basis)
    g. How intuitive is it?

********** About the Feedback Styles **********

4. How would you like to have been given this information?
    a. Which feedback style did you like the most and why?
    b. Which did you like the least and why?
    c. Which aspects from each did you prefer and why?
    d. How would you like to see the feedback the next time you use this interface?
5. How was the flow of information? Did it make logical sense to you?

a. Did you go through all the options?

b. Did you dislike a particular screen?
Would you prefer if a specific screen was changed or improved or deleted?
(or any other particular aspect in any screen?)

6. Would you consider this as a medical diagnosis? Why?
7. What do you think about the timers?

8. Was anything in particular hard to understand? Is there a need for further instructions?
9. Do you see any barriers in using this technology?
10. After having seen the screens and the final results page, what are your opinions on the way the information was displayed?

    a. Were you surprised by the results?
    (did you expect the score you got?)

11. Would you be willing to use it again?
12. What were your opinions about the 'Pause Screen'
13. What were you thinking of when answering the Pause Screen questions?

---------- Use of information ----------

14. What are you planning to do with this information?

    a. Are there specific driving habits that you are planning to change?

    b. Do you plan on following up with a doctor? Yes or No? Why?

    c. Who would you be comfortable sharing this information with?

---------- Compare to paper-pen versions----------

1. What is your opinion about the difference in paper-pen version of the test and the digital?
    a. Which is more comfortable?
    b. Did you notice any struggles with the digital version?

2. What do you think about the difference in scores?

Appendix F

Interview Guide: Phase-1 Study

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SEMI-STRUCTURED **INTERVIEW GUIDE**

After use of application

Note: I will be using the term "application" for the entire digital tool that was presented to you and the word "interface" for just the look/feel/colors and such.
If you are not clear on what I am referring to or asking, please stop me at any time and I would be happy to discuss.

1. How did you feel after using the application?
   (Gauging immediate reactions)
2. What do you think the purpose of this application is?
   (Identify if additional information or explanation is needed regarding its intent)
3. Was the application engaging? Why / why not?
   (Understanding if using the application created positive or negative moods)
    a. How did you feel about each of the tasks you performed?(Prompt if necessary: stress, etc.)
        i. TMT: _____
        ii. Mazes: _____
        iii. Targets: _____
4. Was anything hard to follow or understand?
   (Theme: Design Accessibility, Sub-theme: Navigation)
    a. Would you have liked to have more instructions?
       If so, in which place(s) and what would you have liked to know?
       (Design Improvements)
5. How do you think these skills relate to driving?
   (Theme: Trust, Sub-theme: Applicability to Driving)

a. How do you think your driving skills may change over time now? Why?
   (Themes: Awareness (1), Motivations for Use (2))

6. Thinking about the number of tasks you were asked to do in the application, do you feel there were too few, too many, or just the right amount?
   (Theme: Trust, Sub-theme: Applicability to Driving)

7. How much time would you likely spend (weekly or monthly) for this application?
   (Theme: Accessibility, sub-theme: Availability of time)
   Note: Please answer these questions to reflect prior to the current COVID-19 situation

   a. Do you see any barriers to you using this application, If so what might those be?
      Rephrased: things that would make it difficult for you to use this
      (Theme: Accessibility, time and device)

8. What are your feelings regarding the summary screen?

   a. Were your results unexpected?
      (Theme: Awareness)

   b. Is there anything you would like to see changed? If so, how?
      (Theme: Trust, Sub-theme: Feedback tone, Score explainability)

   c. How helpful is the information presented?
      (Theme: Action plan (1), Motivations for use (2))

   d. Is there additional information you would like to see, if so what?
      (Design Improvements)

   e. Are there additional changes you would like to see?

9. Would you consider this as a medical diagnosis? Why?
   Follow-up: If the number of activities were expended?
   (Theme: Trust, sub-theme: Feedback tone)

10. Is this application something you would use again?
    (Theme: Motivations for use)

---------- Pause Screen & Driving Plan----------

11. Did you have a driving plan before you interacted with this application?

a. If yes, what was it?
   And has this experience changed that plan?

b. If not, would this prompt you to create one?
   What might it be?

12. What did you think about the Pause Screen questions?

    a. Do you regard them as helpful in planning for the future?

    b. Would you change the way they were presented, if so how?

    c. Would the score summary help change your driving plan over time, why or why not?

---------- Use of information ----------

13. What are you planning to do with this information?
    (Themes: Trust, Action Plan)

    a. Are there specific driving habits that you are planning to change?

    b. If yes to above, how do you plan on going about with these changes?
       (If not for COVID, let's say)...

    c. Who would you be comfortable sharing this information with?

    d. Do you plan on following up with a doctor? Yes or No? Why?

---------- COVID-19 changes in driving----------

14. Has the current situation regarding COVID-19 changed your usual driving habits?
    If so, how?

Appendix G

Interview Guide: Phase-2 Study

UNIVERSITY OF WATERLOO

SEMI-STRUCTURED INTERVIEW GUIDE
Phase 2 interviews

1. How was the experience this time around with the application?

   Prompts:

   Have you observed any change in the user experience while using this interface from the previous version?

   How did your experience differ with this version compared to the previous?

2. Did you notice any changes to the application? If yes, please list each?
3. For each change mentioned and unnoticed, use prompts:
   a. Why do you think the change was made?
   b. What did you think about it?
   c. What did you like or dislike?

      (Researcher explains the issue that was addressed through the modification)
   d. What alternative designs do you think would address the issue instead?
   e. Please scale the effectiveness of the changes made out of 10 (where 1 is least effective and 10 is most effective).
   f. Why the above score?
4. Has this version changed your opinion about your driving?

   (follow up: and compared to the previous one)?

   If so, how?

   (Usefulness)

   (Usability)

- What would make you more likely to use this application?
- What would make you want to use this application if you heard about it in a casual conversation or became aware of it by chance?

**Is there anything we haven't discussed that you would like to mention?

Appendix H

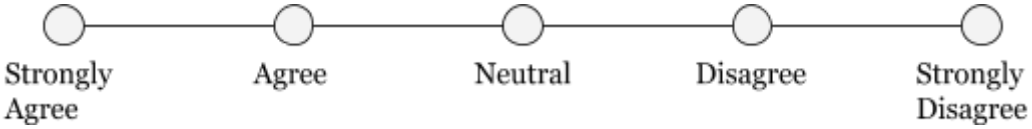
Usability Survey: Pilot Study

UNIVERSITY OF WATERLOO

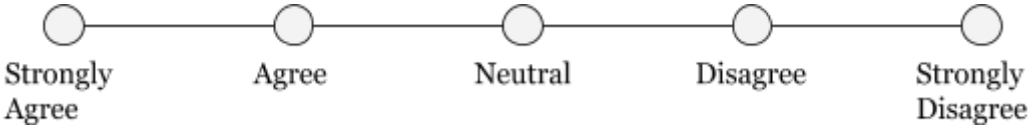
USABILITY SCALE

Please put a check mark on the circle that you feel most appropriate.

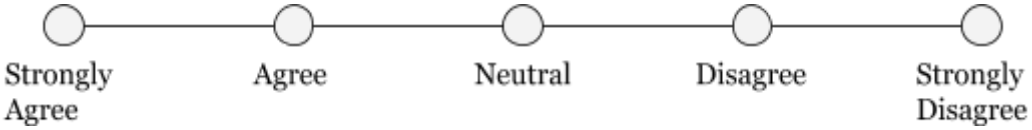
- I think that I would like to use SmartDrive if and when needed (~once in 2 months)



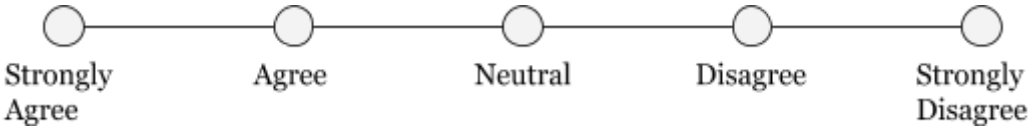
- I found SmartDrive unnecessarily complex



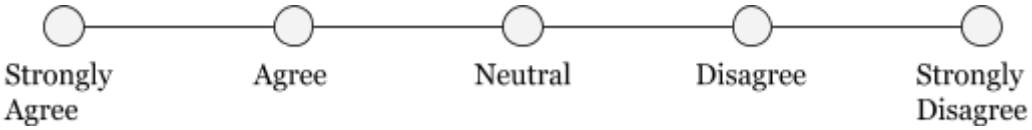
- I thought SmartDrive was easy to use.



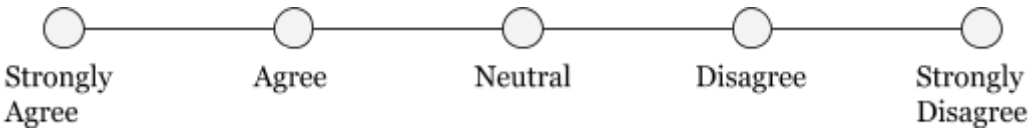
- I think that I would need the support of a technical person to be able to use SmartDrive



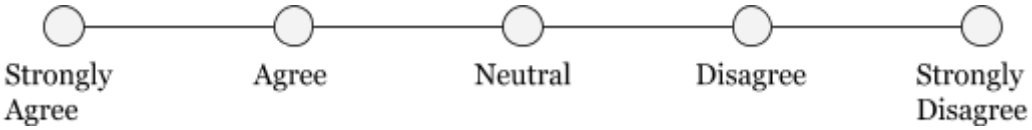
- I found the various functions (buttons, screens) of SmartDrive were easy to understand and use.



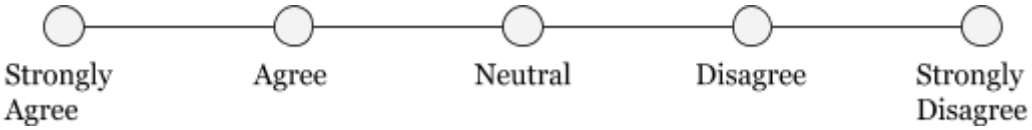
- I thought the colors and layout of the screens weren't consistent and clear



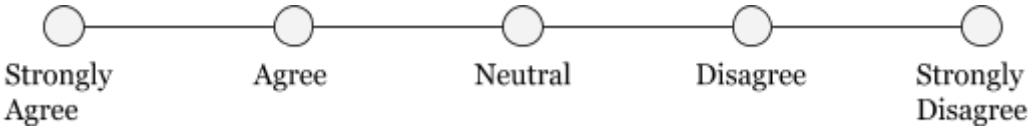
- I would imagine that most people would learn to use SmartDrive very quickly.



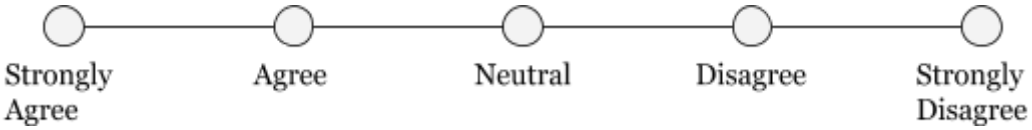
- I found SmartDrive very cumbersome to use



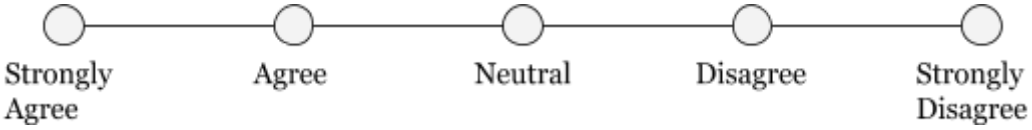
- I felt very comfortable using SmartDrive



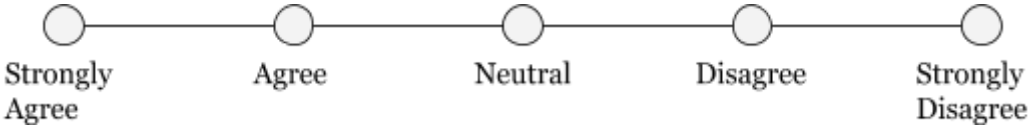
- I felt very confident using SmartDrive



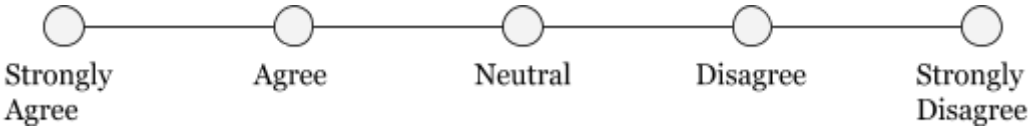
- I needed to learn a lot of things before I could start using SmartDrive



- I think I would need some assistance to use SmartDrive at home



- I felt stressed using SmartDrive



Appendix I

Usability, Usefulness, Design Survey: Phase-1 & Phase-2 Studies

SmartDrive Usefulness Survey

. Please answer these questions to reflect prior to the COVID-19 pandemic.

. Please type the participant code given to you by the researcher

1.. SmartDrive made me realize some driving-related concerns I have.

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

2.. Using SmartDrive helped me to think critically about my driving

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

3.. Using SmartDrive enhanced my knowledge about my driving.

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

4.. I think SmartDrive would give me greater control over thinking and talking about my driving

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

5.. SmartDrive would make discussions about my driving with anyone easier

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

6.. Using SmartDrive encouraged me to think about the future of my driving

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

7.. Using SmartDrive could give me greater control over my driving future

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

8.. SmartDrive provided helpful guidance and instructions for performing the tasks.

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

9.. Overall, I find SmartDrive useful.

- ☐ Agree
- ☐ Neutral
- ☐ Disagree

App design Survey

10.. SmartDrive has a pleasing color scheme

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

11.. SmartDrive is easy to navigate

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

12.. SmartDrive has good visuals and images

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

13.. SmartDrive uses simple language

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

14.. Information provided was clear and easy to read

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

15.. Instructions for all the tasks were clear

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

16.. Instructions for all the tasks were sufficient

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

17.. Overall, I like the design of SmartDrive

- ○ Agree
- ○ Neutral

○ Disagree

Ease of Use Survey

Q18. On average, I would use SmartDrive...

Once a week	Less often than once a week but more than once a month	Once a month	Less often than once every three months but more than once a year	Once a year	Never
○	○	○	○	○	○

Q19. I found SmartDrive unnecessarily complex

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

Q20. I thought SmartDrive was easy to use.

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

Q21. I think that I would need the support of a technical person to be able to use SmartDrive

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

Q22. I found the various functions of SmartDrive (i.e. how it works) were easy to understand and use.

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

Q23. I thought the colors and layout of the screens were inconsistent

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

Q34. I thought the colors and layout of the screens were unclear

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

Q24. I imagine that most older adults would learn to use SmartDrive very quickly.

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

Q25. I found SmartDrive cumbersome to use

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

Q26. I felt comfortable using SmartDrive

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

Q27. I felt confident using SmartDrive

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

Q28. I needed to learn a lot of things before I could start using SmartDrive

Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
○	○	○	○	○

Appendix J

Self-rating Scale: Pilot, Phase-1 & Phase-2 studies

Drivers 65 Plus: Check Your Performance

A Self-Rating Tool with Facts and Suggestions for Safe Driving

AAA Foundation for Traffic Safety

As a mature driver, you bring a wealth of experience to the driver's seat.

By the year 2030, one of every five drivers in America will be 65 years of age or older. Freedom to travel by automobile will continue to be an important factor to maintain personal independence and mental health. The central idea of this booklet is to help you drive as long as safely possible.

Age should never be used as the sole indicator of driving ability. In fact, drivers 65 and older represent a wide range of abilities, and no individual should have his or her driving privileges determined solely on their age. However, it is not uncommon for some of the skills necessary for safe driving – vision, reflexes, flexibility, and hearing – to begin to deteriorate as we age.

If you notice that you are beginning to experience some of these natural age-related changes, you can adjust your driving habits to keep driving safely – after all, one of the most critical assets for safe driving is experience, and experience does *not* decline with age. It's important to recognize your limitations and to be aware of everything you can do to be safe on the road.

Drivers 65 Plus

Introduction

Think about what tasks you do every time you get behind the wheel of a car. You must coordinate the actions of your hands, feet, eyes, ears, and body movements. At the same time, you must decide how to react to what you see, hear, and feel in relation to other cars and drivers, traffic signs and signals, conditions of the highway, and the performance of your car.

These decisions are usually made close to other vehicles and must be converted quickly into action — brake, steer, accelerate, or a combination of these — to maintain or adjust your position in traffic. And these decisions must be made frequently.

As a mature driver, you bring a wealth of experience to the driver's seat; that is why, on average, drivers in their fifties and sixties have just about the lowest crash rates of anyone on the road. However, as some of the skills required for optimal driving performance begin to decline at older ages, research shows that crash rates begin to increase as drivers reach their late 60's or early 70's, and increase more rapidly after about age 75.

Additionally, your body is not as resistant to injury as it might have been 30 or 40 years ago. If you are involved in a crash, you are likely to suffer more serious injuries as compared to a younger person in a similar crash. This makes it increasingly important for you to do everything you can to keep your driving skills sharp and to minimize your chances of being involved in a crash in the first place.

Purpose of this Booklet.

This self-rating form is designed to help you examine your ability to keep driving safely. Through knowledge and self-awareness, you can make better informed decisions about when to get behind the wheel and when to seek other forms of transportation.

The rating form on the next page is for your private use.
Answer the 15 questions as honestly as possible. Use the rating guide to compute your score and to identify your strengths and weaknesses.
Next, read the *Suggestions for Improvement* section that corresponds to each question to see how you can improve your driving.

Now, please follow the instructions on pages 2 and 3.

Drivers 65 Plus: Self-Rating Form ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★

INSTRUCTIONS: For each of the following 15 questions, check the symbol (✓) of the one answer that best describes you.

	Always or Almost Always	Some-times	Never or Almost Never
1. I signal and check to the rear when I change lanes	○	□	□
2. I wear a seat belt	○	□	□
3. I try to stay informed on changes in driving and highway laws and techniques	○	△	□
4. Intersections bother me because there is so much to watch from all directions	□	△	○
5. I find it difficult to decide when to merge with traffic on a busy interstate highway	□	△	○
6. I think I am slower than I used to be in reacting to dangerous driving situations	□	□	○
7. When I am really upset, it affects my driving	□	□	○
8. My thoughts wander when I drive	□	△	○
9. Traffic situations make me angry	□	△	○
10. I get regular eye exams to keep my vision at its sharpest	○	□	□
11. I check with my doctor or pharmacist about how the medications I take affect my driving ability. (If you do not take any medication, skip this question)	○	□	□
12. I try to stay informed of current information about health and wellness habits	○	△	□
13. My children, other family members or friends have expressed concern about my driving ability	□	△	○
Note new headings:	**None**	**One or Two**	**Three or More**
14. How many traffic tickets, warnings, or "discussions" with law enforcement officers have you had in the past two years?	○	△	□
15. How many collisions (major or minor) have you had during the past two years?	○	□	□

Self Scoring: Count the number of checkmarks in the squares and record the total in the square below. Follow the same procedure for the triangles and circles.

□ △ ○ **These are your Check Mark Totals. For score and interpretation, see next page.**

★ ★

Scoring: **There are 5 steps.**

Step 1: Write the Check Mark Total recorded in the square on the previous page in the square to the right. □ X 5 = _____

Step 2: Write the Check Mark Total recorded in the triangle on the previous page in the triangle to the right. △ X 3 = _____

Step 3: Multiply the number in the square by 5.

Step 4: Multiply the number in the triangle by 3.

Step 5: Add the results of Steps 3 and 4. YOUR SCORE IS _____

Interpretation of Score:

The lower the score, the safer you are as a driver.

The higher the score, the more danger you are to yourself and others.

No matter what your score, look at the *Suggestions for Improvement* section for each area in which you checked a square or triangle. These are the areas in which you can improve the most.

Score	Meaning
0 to 15	**GO!** You are aware of what is important to safe driving and are practicing what you know. See the *Suggestions for Improvement* in the following section of this booklet, to learn how to become an even safer driver.
16 to 34	**CAUTION!** You are engaging in some practices that need improvement to ensure safety. Look to the *Suggestions for Improvement* section to see how you might enhance your driving.
35 and over	**STOP!** You are engaging in too many unsafe driving practices, and might pose a hazard to yourself and others. Examine the areas where you checked squares or triangles. Read the *Suggestions for Improvement* section for ways to correct these problem areas.

These scores are based on what drivers 65 and over have told us about driving practices and habits. Your score is based on your answers to a limited number of important questions. For a complete evaluation of your driving ability, many more questions would be required, along with medical, physical, and licensing examinations. Nevertheless, your answers and score give some indication of how well you are doing and how you can become a safer driver.

In general, a checked square for an item reflects an unsafe practice or situation that should be changed immediately. A checked triangle means a practice or situation that is unsafe, or on its way to becoming unsafe, if nothing is done to improve it. Checking circles is a sign that you are doing what you should to be (and remain) a safe driver.

Most of the square and triangle answers represent practices or situations that can be improved by most drivers. The following section contains suggestions for improvement, divided into each of the 15 areas. You should focus on those areas for which you checked squares or triangles.

Drivers 65 Plus: Suggestions for Improvement

1 I signal and check to the rear when I change lanes.

Checking rearview and side mirrors, looking to the rear to cover the blind spots, and signaling well before your maneuver are the only ways to avoid hitting a car when changing lanes.

But why don't you do these things all the time? In some cases, you might simply forget. In observational studies older drivers report being unaware of having failed to look to the rear before changing lanes or backing up. Many of our driving habits are exactly that – habits. And we can stop being aware of our actions, especially if we've driven crash-free for a long time.

Many older drivers stop looking over their shoulders because of decreased flexibility. If you have arthritis, then you know how painful a quick look over the shoulder can be.

If looking over your shoulder to check for traffic is difficult for you, try to:

- Drive with a partner to act as a co-pilot whenever possible.
- Install extra-wide rearview mirrors and side mirrors to decrease your blind spots. You'll need to learn how to use the side mirrors correctly, because those of convex lens design can make objects appear smaller and farther away than they actually are.
- Ask your physician about medications and exercises that might improve your flexibility; the AAA Foundation for Traffic Safety has a brochure available online at ***AAAFoundation.org*** called *A Flexibility Fitness Training Package for Improving Older Driver Performance* to help you improve your flexibility.
- Take a re-training or refresher course that helps older drivers adjust to the limitations due to aging. Call your local AAA club to see if they offer a course.
- Make a concerted effort to be aware of your driving habits and decide to always look before changing lanes.

2 I wear a seat belt.

Seat belts cut your risk of death nearly in half if you are involved in a serious crash, and of course, it's the law in nearly every state. Even if you plan to drive only short distances under ideal conditions, it makes sense to wear your seat belt every time you ride.

To provide optimal protection, seat belts should be worn properly with the shoulder belt across your shoulder and upper thigh bones, because serious injury can occur if not worn properly. Fastening your seat belts is unquestionably the single best way to protect yourself in a crash.

You can increase your chances of surviving a collision or reducing injury by taking the following steps:

- Wear your seat belt properly at all times.
- If your seat belt is extremely uncomfortable or cannot be properly fastened, take it to a competent mechanic for alterations. Many cars have adjustable shoulder belt mounts or you can buy devices that improve the fit.
- If your car does not have an automatic reminder to fasten seat belts, leave yourself a note on the dashboard or sun visor. Remind your passengers to buckle up.

Wear your seat belt correctly... across your shoulder and chest - NOT under an arm, across your hip bones - NOT your stomach. It's comfortable... it's easy.

***New York Coalition for Safety Belt Use Medical Society. State of New York**

3 I try to stay informed on changes in driving and highway laws and techniques.

With new roads being built, new traffic signals being installed, and intersections being converted into traffic circles or roundabouts in an increasing number of cities, it is critical for you to continually refresh your knowledge of the roads and traffic patterns near where you drive.

Knowledge of signs and symbols can help you, especially if your ability to see them is diminishing. Sometimes, just knowing what the shapes of signs mean can help you anticipate their message. Familiarity and knowing what to do can eliminate hesitation and uncertainty when you need to make a quick decision.

We all want to share the road safely, so we need to understand traffic laws, devices, signs, and symbols. Here's how you can learn more about them:

- Call, visit or go online to your state's motor vehicle administration to obtain the current drivers licensing manual for your state. Study the manual as though you were taking the test. Ask if they have other ways for you to stay current.
- Take a re-training or refresher course. Contact your local AAA club to find a course near you or visit ***AAASeniors.com.***
- Make a point of checking your local newspapers for changes in traffic patterns and special intersections or signage, so you feel prepared and confident.

4 Intersections bother me because there is so much to watch from all directions.

Intersections are dangerous for all of us. You must interact with other drivers and pedestrians whose movements and decisions are difficult to anticipate. In fact, crashes at intersections are quite common among older drivers, especially when left-turns are required.

How comfortable you feel around intersections can be an early warning sign that you need a refresher course or other assistance. Listen to your instincts and take a good look at your driving skills. What bothers you most about intersections? Is it an inability to handle all the information quickly enough? Are you unsure about how to position the car for a left or right turn? Do you find it difficult to turn the steering wheel because of arthritis or some other physical problem? Is it hard to judge the speed of oncoming vehicles? Sometimes, this sort of analysis can lead you to solutions.

If you find intersections difficult, review the following steps for improvement:

- If one or two intersections on your regular routes give you particular trouble, study them while on foot. Watch the problems other drivers have to handle. Notice how the traffic signals assist drivers and pedestrians. This way you know in advance what the common problems are and how to handle them when they occur. This kind of analysis can help you handle other intersections as well.
- Plan your trips to avoid busy intersections or use them at less congested times. Plan an alternate route to avoid left turns from busy intersections. Remember that making three right turns can help you avoid turning left. In many places you will be able to do this by driving straight through the intersection, turning ***right*** at the next street, and then making two more right turns. Then, you end up driving straight through the original intersection in the direction that you originally wanted to go.
- Take a re-training or refresher course that helps older drivers adjust to the limitations of age. What you learn may give you the confidence to recognize that you can handle intersections correctly.

Appendix K

Self report of diagnosis of dementia

UNIVERSITY OF WATERLOO

SELF REPORT OF DIAGNOSIS

To better understand the difference in performances (when using the digital tool we've designed) between those who do not have dementia and those who do, we ask for people to self-report whether or not they have a dementia diagnosis.

This is a strictly **confidential** questionnaire. Only a randomly generated participant ID number, assigned by the research administrator will be on this questionnaire.
All hard copy data will be stored in locked cabinets that will be accessible only to researchers and will be shredded after 7 years.
All soft copy data will be securely stored in password protected lab servers of the principal investigators and access will be restricted to the research team. Your name will not appear in any report, presentation or publication resulting from this research.

☐ I confirm that **I have not** been diagnosed with dementia

☐ I confirm that **I have** been diagnosed with dementia

If yes, please specify the following details (optional)

Date of diagnosis:

_____/_____ (MM)/(YYYY)

Type of dementia: _____

Any other information you would like the researchers to know:

_____

_____

_____

Appendix L

Follow-up Interview Guide

UNIVERSITY OF WATERLOO

FOLLOW-UP INTERVIEW QUESTIONS

2 weeks post previous interview

(Using the BCSS model)

Project Title: Prototype testing of a digital interface that enables older adults to self-assess their driving ability.

Note: Please answer these questions to reflect prior to the current COVID-19 situation

Questions:

1.a. Now that it has been a few weeks since the study, have you thought about your driving style since?

1b) Have you driven since the study?

Prompt: Notice any changes while driving?

Alternate: Did you intend to change your driving style in any manner?

2. Have you considered creating a driving plan? OR

2- follow up: If **Yes**, what have you considered?
Why did you decide to make these changes?

2- follow up: If **No**, why not?

3. If the SmartDrive app were made available to you now, would you be interested in doing another self-assessment?

4. Have you talked with anyone about your driving experience since the study?

Alternate: Do you intend to talk to anyone about your driving experience?

Appendix M

Study Poster: Phase-2 Study

Evaluation of SmartDrive

Systems Design Engineering, University of Waterloo

You are Invited to Participate in an Online Research Study on Self-assessment of Driving

Have you been diagnosed with mild cognitive impairment or dementia and are interested in exploring a driving self-assessment application?

Researchers at University of Waterloo are creating a new way for older adults to self-assess their ability to drive. We are seeking participants who are interested in interacting with a prototype online and sharing their thoughts on its usability and effectiveness in delivering feedback about driving.

You are invited to participate if you are above 60 years, have been diagnosed with mild cognitive impairment or dementia and

- are currently driving
  OR
- have recently (past 6 months) stopped driving.

Participants will be invited to take part in a 2-hour online interview to try out the prototype and a 10 minute follow-up phone call two weeks post the study to share their opinions on the application and their experience.

Participants will receive $25 for their participation in the study.

For more details, please contact Surya Neti (Study Co-Investigator):
519-888-4567 ext 38328 | ssneti@uwaterloo.ca

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee

itwil

UNIVERSITY OF WATERLOO

Appendix N

Study Poster: Phase-2 Study

Simple Driving Assessment

This simple driving assessment will help evaluate whether a senior driver needs to take steps to improve their driving skills, and pinpoint specific areas for improvement. It should take 10-15 minutes to complete the assessment.

Instructions:

For each of the following 15 questions, check the symbol (✔) of the one answer that best describes you.

	Always or Almost Always	Some-times	Never or Almost Never
1. I signal and check to the rear when I change lanes.....	○	□	□
2. I wear a seat belt.....	○	□	□
3. I try to stay informed on changes in driving and highway laws and techniques.....	○	△	□
4. Intersections bother me because there is so much to watch from all directions.....	□	△	○
5. I find it difficult to decide when to merge with traffic on a busy highway.....	□	△	○
6. I think I am slower than I used to be in reacting to dangerous driving situations.....	□	□	○
7. When I am really upset, it affects my driving.....	□	□	○
8. My thoughts wander when I drive.....	□	△	○

Simple Driving Assessment

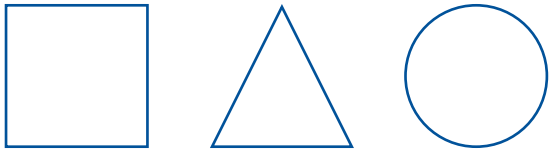
	Always or Almost Always	Some-times	Never or Almost Never
9. Traffic situations make me angry.....	□	△	○
10. I get regular eye exams to keep my vision at its sharpest...	○	□	□
11. I check with my doctor or pharmacist about how the medications I take affect my driving ability. *(If you do not take any medication, skip this question)*.....	○	□	□
12. I try to stay informed of current information about health and wellness habits.....	○	△	□
13. My children, other family members or friends have expressed concern about my driving ability.....	□	△	○

	None	One or Two	Three or More
14. How many traffic tickets, warnings, or "discussions" with law enforcement officers have you had in the past two years?.....	○	△	□
15. How many collisions (major or minor) have you had during the past two years?.....	○	□	□

Simple Driving Assessment

Self Scoring:

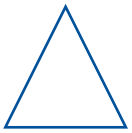
Count the number of checkmarks in the squares and record the total in the square below. Follow the same procedure for the triangles and circles.



These are your Check Mark Totals.
For score and interpretation, see below.

Calculate Your Scoring:

Step 1: Write the Check Mark Total recorded from the square above into the square on the right.....  x 5 = _____

Step 2: Write the Check Mark Total recorded from the triangle above into the triangle on the right.....  x 3 = _____

Step 3: Multiply the number in the square by 5.

Step 4: Multiply the number in the triangle by 3.

Step 5: Add the results of Steps 3 and 4. **YOUR SCORE IS:** _____

Interpretation of Score:

In general, a checked square for an item reflects an unsafe practice or situation that should be changed immediately. A checked triangle means a practice or situation that is unsafe, or on its way to becoming unsafe, if nothing is done to improve it. Checking circles is a sign that you are doing what you should to be (and remain) a safe driver.

Simple Driving Assessment

Interpretation of Score:

No matter what your score, look at the areas where you need to improve by reviewing the questions. Review the information in the CAA Seniors Driving portal to find advice and tips that can help you maintain your driving skills. If you feel there are areas that you can't improve yourself, talk to your doctor or a loved one about making adjustments to your driving habits.

Score Meaning:

0 to 15 ***GO!*** You are aware of what is important to safe driving and are practicing what you know. Review the CAA Seniors Driving information, and take steps to maintain your driving skills.

16 to 34 ***CAUTION!*** You are engaging in some practices that need improvement to ensure safety. Talk to a doctor or a loved one about adjusting your driving habits, such as limiting driving at night.

35+ ***WARNING!*** It might be time to talk to a doctor or a loved one about changing your driving habits to ensure your safety, and the safety of other people on the road. This doesn't mean you have to give up your keys. More information on determining readiness to drive and on consulting a medical professional can be ***found here***.

These scores are based on what drivers 65 and over have stated about driving practices and habits.

Your score is based on your answers to a limited number of important questions. For a complete evaluation of your driving ability, many more questions would be required, along with medical, physical, and licensing examinations. *This evaluation is in no way intended to take place of a comprehensive evaluation by a doctor, and should simply be used as an indicator of your driving skills*.

Appendix O

Trail Making Test, Parts A & B

Trail Making Test (TMT) Parts A & B

Instructions:

Both parts of the Trail Making Test consist of 25 circles distributed over a sheet of paper. In Part A, the circles are numbered 1 – 25, and the patient should draw lines to connect the numbers in ascending order. In Part B, the circles include both numbers (1 – 13) and letters (A – L); as in Part A, the patient draws lines to connect the circles in an ascending pattern, but with the added task of alternating between the numbers and letters (i.e., 1-A-2-B-3-C, etc.). The patient should be instructed to connect the circles as quickly as possible, without lifting the pen or pencil from the paper. Time the patient as he or she connects the "trail." If the patient makes an error, point it out immediately and allow the patient to correct it. Errors affect the patient's score only in that the correction of errors is included in the completion time for the task. It is unnecessary to continue the test if the patient has not completed both parts after five minutes have elapsed.

Step 1: Give the patient a copy of the Trail Making Test Part A worksheet and a pen or pencil.

Step 2: Demonstrate the test to the patient using the sample sheet (Trail Making Part A – *SAMPLE*).

Step 3: Time the patient as he or she follows the “trail” made by the numbers on the test.

Step 4: Record the time.

Step 5: Repeat the procedure for Trail Making Test Part B.

Scoring:

Results for both TMT A and B are reported as the number of seconds required to complete the task; therefore, higher scores reveal greater impairment.

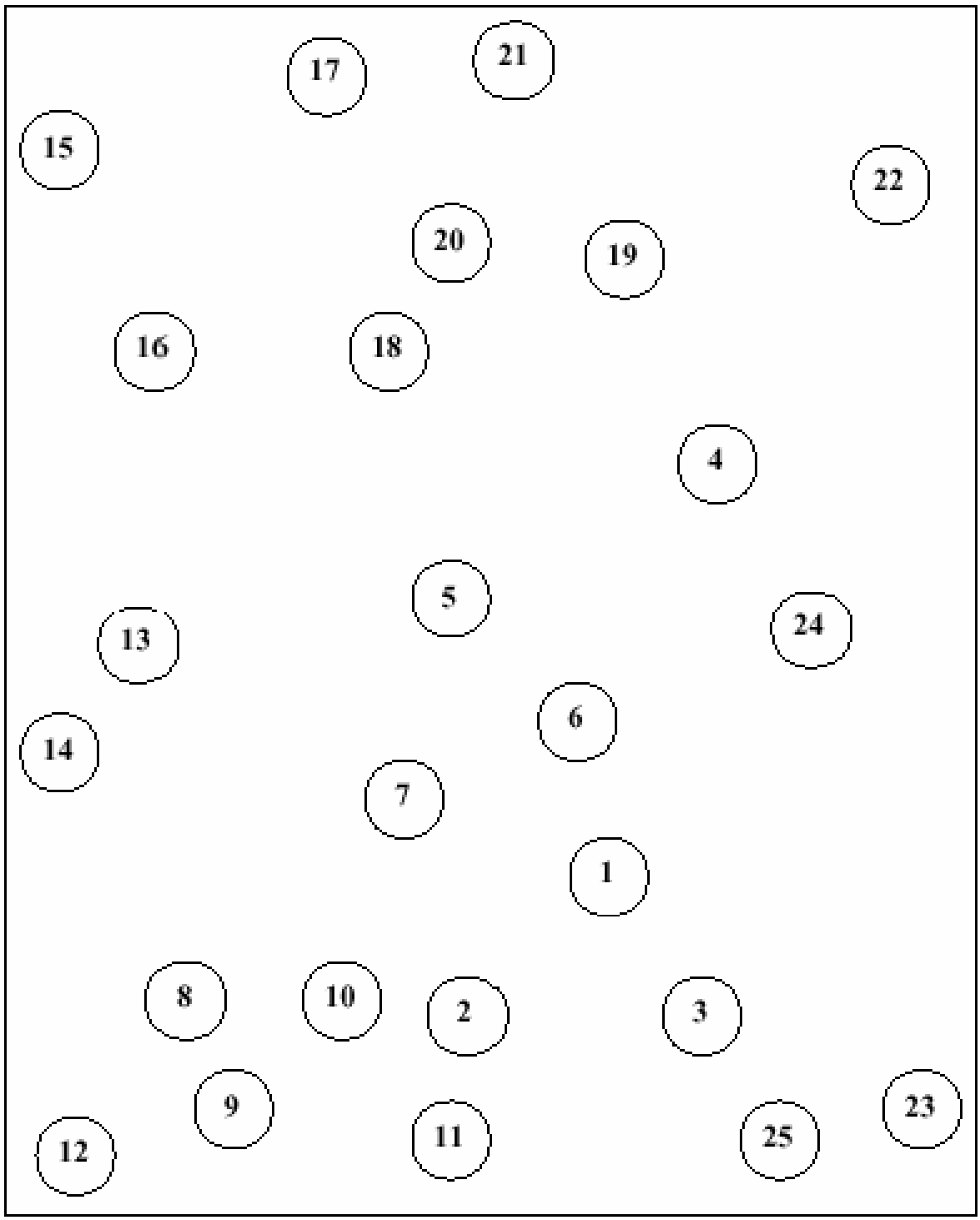
	Average	**Deficient**	**Rule of Thumb**
Trail A	29 seconds	> 78 seconds	Most in 90 seconds
Trail B	75 seconds	> 273 seconds	Most in 3 minutes

Sources:

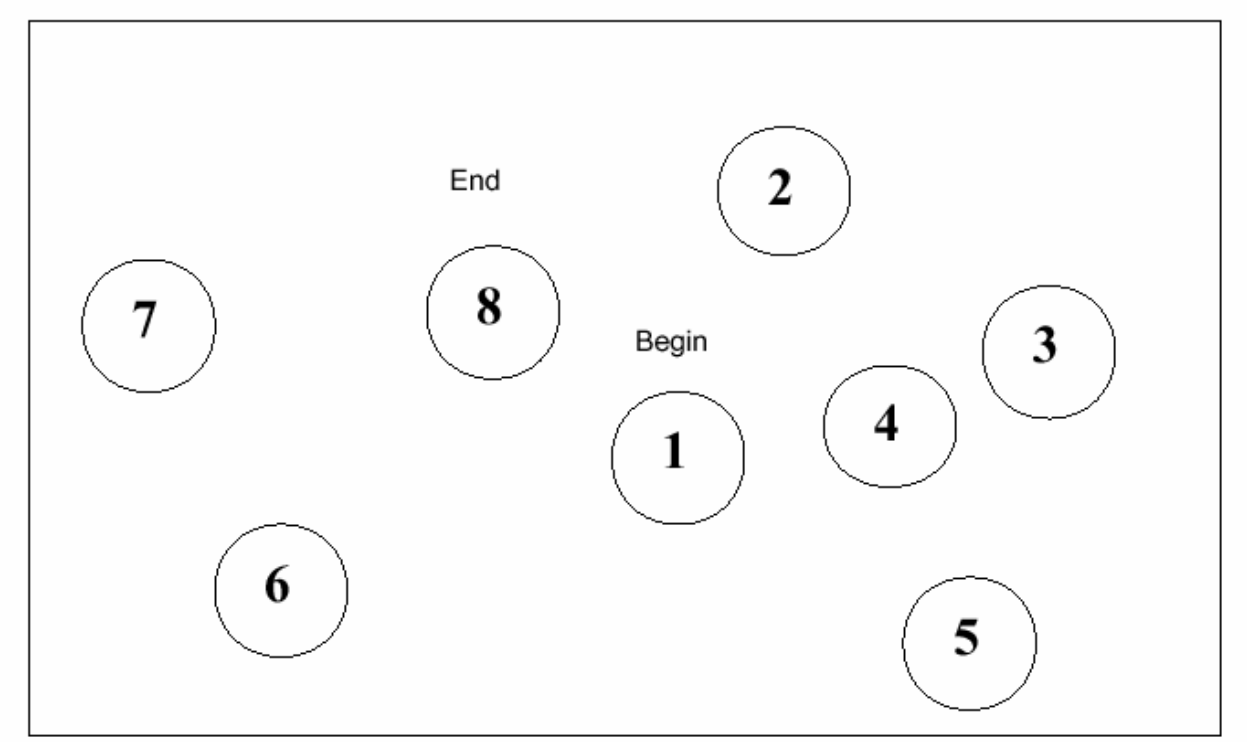
- Corrigan JD, Hinkeldey MS. Relationships between parts A and B of the Trail Making Test. *J Clin Psychol*. 1987;43(4):402–409.
- Gaudino EA, Geisler MW, Squires NK. Construct validity in the Trail Making Test: what makes Part B harder? *J Clin Exp Neuropsychol*. 1995;17(4):529-535.
- Lezak MD, Howieson DB, Loring DW. *Neuropsychological Assessment*. 4th ed. New York: Oxford University Press; 2004.
- Reitan RM. Validity of the Trail Making test as an indicator of organic brain damage. *Percept Mot Skills*. 1958;8:271-276.

Trail Making Test Part A

Patient's Name: _____ Date: _____

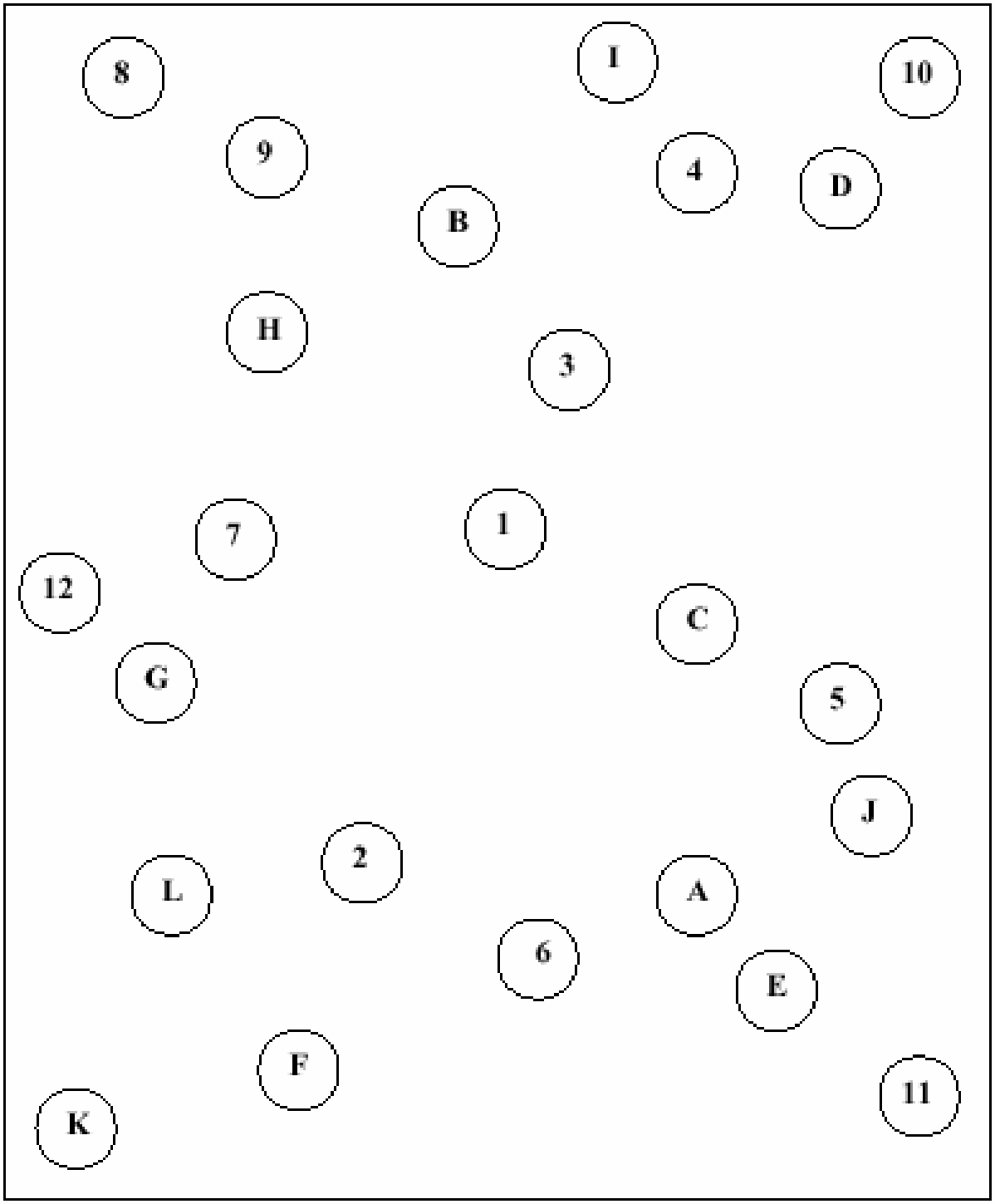


Trail Making Test Part A – *SAMPLE*



Trail Making Test Part B

Patient's Name: _____ Date: _____



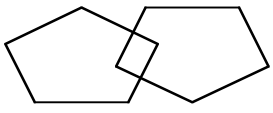
Appendix P

Mini-Mental State Examination

Mini-Mental State Examination (MMSE)

Patient's Name: _____ Date: _____

Instructions: Score one point for each correct response within each question or activity.

Maximum Score	Patient's Score	Questions
5		"What is the year? Season? Date? Day? Month?"
5		"Where are we now? State? County? Town/city? Hospital? Floor?"
3		The examiner names three unrelated objects clearly and slowly, then the instructor asks the patient to name all three of them. The patient's response is used for scoring. The examiner repeats them until patient learns all of them, if possible.
5		"I would like you to count backward from 100 by sevens." (93, 86, 79, 72, 65, …) Alternative: "Spell WORLD backwards." (D-L-R-O-W)
3		"Earlier I told you the names of three things. Can you tell me what those were?"
2		Show the patient two simple objects, such as a wristwatch and a pencil, and ask the patient to name them.
1		"Repeat the phrase: 'No ifs, ands, or buts.'"
3		"Take the paper in your right hand, fold it in half, and put it on the floor." (The examiner gives the patient a piece of blank paper.)
1		"Please read this and do what it says." (Written instruction is "Close your eyes.")
1		"Make up and write a sentence about anything." (This sentence must contain a noun and a verb.)
1		"Please copy this picture." (The examiner gives the patient a blank piece of paper and asks him/her to draw the symbol below. All 10 angles must be present and two must intersect.) 
30		TOTAL

Interpretation of the MMSE:

Method	Score	Interpretation
Single Cutoff	<24	Abnormal
Range	<21	Increased odds of dementia
	>25	Decreased odds of dementia
Education	21	Abnormal for 8th grade education
	<23	Abnormal for high school education
	<24	Abnormal for college education
Severity	24-30	No cognitive impairment
	18-23	Mild cognitive impairment
	0-17	Severe cognitive impairment

Interpretation of MMSE Scores:

Score	Degree of Impairment	Formal Psychometric Assessment	Day-to-Day Functioning
25-30	Questionably significant	If clinical signs of cognitive impairment are present, formal assessment of cognition may be valuable.	May have clinically significant but mild deficits. Likely to affect only most demanding activities of daily living.
20-25	Mild	Formal assessment may be helpful to better determine pattern and extent of deficits.	Significant effect. May require some supervision, support and assistance.
10-20	Moderate	Formal assessment may be helpful if there are specific clinical indications.	Clear impairment. May require 24-hour supervision.
0-10	Severe	Patient not likely to be testable.	Marked impairment. Likely to require 24-hour supervision and assistance with ADL.

Source:

- Folstein MF, Folstein SE, McHugh PR: "Mini-mental state: A practical method for grading the cognitive state of patients for the clinician." *J Psychiatr Res* 1975;12:189-198.

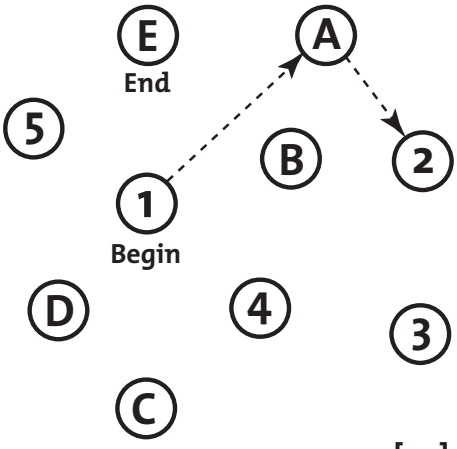
Appendix Q

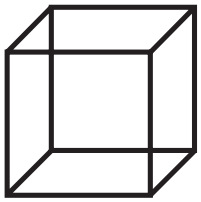
Montreal Cognitive Assessment

MONTREAL COGNITIVE ASSESSMENT (MOCA)

NAME :
Education : Date of birth :
Sex : DATE :

VISUOSPATIAL / EXECUTIVE





Copy cube

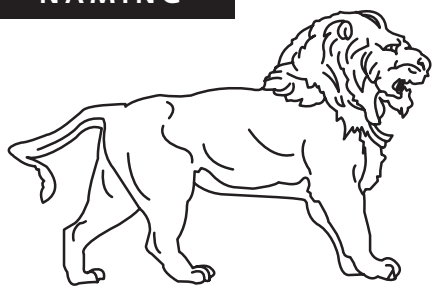
[ ] [ ]

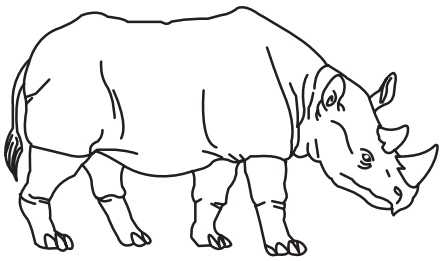
Draw CLOCK (Ten past eleven)
(3 points)

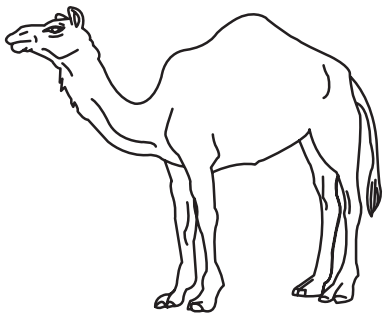
[ ] Contour [ ] Numbers [ ] Hands

POINTS ___/5

NAMING







[ ] [ ] [ ]

___/3

MEMORY

Read list of words, subject must repeat them. Do 2 trials. Do a recall after 5 minutes.

	FACE	VELVET	CHURCH	DAISY	RED
1st trial					
2nd trial					

No points

ATTENTION

Read list of digits (1 digit/ sec.). Subject has to repeat them in the forward order [ ] 2 1 8 5 4

Subject has to repeat them in the backward order [ ] 7 4 2

___/2

Read list of letters. The subject must tap with his hand at each letter A. No points if ≥ 2 errors

[ ] F B A C M N A A J K L B A F A K D E A A A J A M O F A A B

___/1

Serial 7 subtraction starting at 100 [ ] 93 [ ] 86 [ ] 79 [ ] 72 [ ] 65

4 or 5 correct subtractions: **3 pts**, 2 or 3 correct: **2 pts**, 1 correct: **1 pt**, 0 correct: **0 pt**

___/3

LANGUAGE

Repeat : I only know that John is the one to help today. [ ]

The cat always hid under the couch when dogs were in the room. [ ]

___/2

Fluency / Name maximum number of words in one minute that begin with the letter F [ ] _____ (N ≥ 11 words)

___/1

ABSTRACTION

Similarity between e.g. banana - orange = fruit [ ] train – bicycle [ ] watch - ruler

___/2

DELAYED RECALL

	Has to recall words WITH NO CUE	FACE [ ]	VELVET [ ]	CHURCH [ ]	DAISY [ ]	RED [ ]	Points for UNCUED recall only
Optional	Category cue						
	Multiple choice cue						

___/5

ORIENTATION

[ ] Date [ ] Month [ ] Year [ ] Day [ ] Place [ ] City

___/6

 Version November 7, 2004

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Normal ≥ 26 / 30

TOTAL ___/30

Add 1 point if ≤ 12 yr edu

Appendix R

Feedback & Appreciation Letter

FEEDBACK & APPRECIATION

Dear [participant name], Date: _____

I thank you for your participation in our study entitled “Prototype testing of a digital interface that enables older adults to self-assess their driving ability”

As a reminder, the purpose of this study is to test whether a prototype might change perception of driving when given feedback on validated cognitive tasks on a digital interface.

The messages shown in the prototype should not be taken as clinical recommendations. A good or average score is not a valid confirmation of your ability to continue driving. A ‘below average’ score and suggestion to consult with medical staff should not be considered as a medical recommendation.
The point of the research project is to develop this application. Additional testing will be required to validate it.

Thank you for sharing your time and thoughts - we appreciate the feedback you’ve provided on the tool and will use this information to guide the next version.

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE#40677). If you have questions for the Committee contact the Office of Research Ethics, at 1-519-888-4567 ext. 36005 or ore-ceo@uwaterloo.ca.

For all other questions contact Surya Neti at ssneti@uwaterloo.ca.
Please remember that any data pertaining to you as an individual participant will be kept confidential.

If you are interested in receiving more information regarding the results of this study, or would like a summary of the results, please contact the persons mentioned below by email.

Thank you again.

Dr. Jennifer Boger - jboger@uwaterloo.ca, Surya Neti - ssneti@uwaterloo.ca
Department of Systems Design Engineering, University of Waterloo