CENTRE FOR RESEARCH ON AGEING, HEALTH AND WELLBEING
ANU COLLEGE OF MEDICINE, BIOLOGY & ENVIRONMENT

Translation of a validated driver screening tool for clinical assessment and research use

A Report from Research Funded by the NRMA – ACT Road Safety Trust

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By

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Contents

Executive Summary

This report documents the production and translation of a novel evidence-based screening battery designed to identify older drivers at risk of unsafe driving. The screening battery, known as the Multi-D, is based on ten years of older driver research conducted by K Anstey and J Wood. It represents a novel approach to older driver screening that takes into account age-related changes in vision, sensorimotor skills and cognition that are associated with on-road driving. The project involved updating and producing five copies of the Multi-D test battery, along with a manual for test administration and installation, and an instructional video.

Production of the test kits enabled the Multi-D to be translated to other research projects and into a validation study looking at clinical application of the Multi-D in the older driver assessment setting. This NHMRC funded study will be conducted over 5 years and will compare the validity of several driver screening tests including the Multi-D against on-road driving. The study will be run with participants recruited from the community as well as from ACT Health Directorate’s Driver Assessment and Rehabilitation Service, and will include the sharing of experience and knowledge regarding older driver assessment between researchers and practitioners.

The Multi-D will also be used in two large studies that have recently commenced:

- A naturalistic driving study across the lifespan (Ross, L. & Stavros, D. University of Alabama, US)
- The Dancing Mind: cognitive benefits of multi-dimensional physical activity in old age (Merom, D. University of Western Sydney, Australia)

The above research projects and the validation study will contribute to the current body of data on the Multi-D as a predictor of older-adults' driving ability, and also provide data on its sensitivity to changes induced by intervention programs. This information will be used to update and further develop the Multi-D and improve its utility in a clinical setting.

Background

Currently older drivers represent the fastest-growing segment of the driving population in terms of the total number of drivers on the road as well as the number of miles driven annually per driver. In Australia it is estimated that in 2013 approximately 99.3% of males and 89.9% of females aged 65+ will be licensed drivers [1]. Research indicates that driving is important for maintaining older adults' independence and self-esteem. Discontinuation of driving has found to be correlated with depression, isolation and functional impairment [2, 3]. Thus, it is important to ensure that older people can continue driving, however, older drivers also pose a risk for road safety [4-12]. Current criteria for identifying at-risk older drivers in order to refer them for further assessment are largely arbitrary and not based on evidence [13, 14]. Research conducted by Anstey and Woods over the past ten years have demonstrated that the impact of ageing on driving ability is multifactorial – and is influence by age-related changes in vision, balance and cognition [5, 6, 15-18]. This work has led to the development of a brief screening battery, the Multi-D, that has been shown to be highly sensitive to discriminating unsafe older drivers [15]. The present project focused on producing and translating the Multi-D screening battery for translation to clinical assessment and research use.

Driving safety in older adults

There are numerous ways in which crash statistics can be calculated. Incidents may be presented as a proportion of individuals with a driver's licence, as a proportion of the total population, or relative to the distance travelled. Because of age-related changes in driving patterns, some of these *exposure measures* are less accurate than others when examining the age effect on crash statistics. For example, many older drivers may continue to hold a driver's licence without being an active driver [17]. The distance and frequency of driving also changes dramatically with age as individuals retire and self-limit their driving [2, 19, 20]. When these different metrics are compared against traffic related injuries and fatalities, it is apparent that older adults are overrepresented in crashes *per distance travelled,* particularly with regard to serious injuries or death when involved in motor vehicle crashes [8, 21] (see Figure 1). This was confirmed in a 2001 OECD report on road statistics which showed that road fatalities are highest in young drivers and in older drivers [8]. This 'U' shaped curve representing road fatalities across age groups in industrialised countries has been replicated in numerous studies published in peer-reviewed scientific journals. In both the US and Australia, frailty, cognitive impairment, poor physical functioning, and poor health have all been demonstrated to reduce the safety of older drivers [5, 6, 18, 22]. Older drivers are 13 times more likely to be killed in a crash compared to drivers aged 30-59 years and increased frailty (due to reductions in bone strength) contributes to their overrepresentation in injuries/death in crashes compared to younger age groups [22].

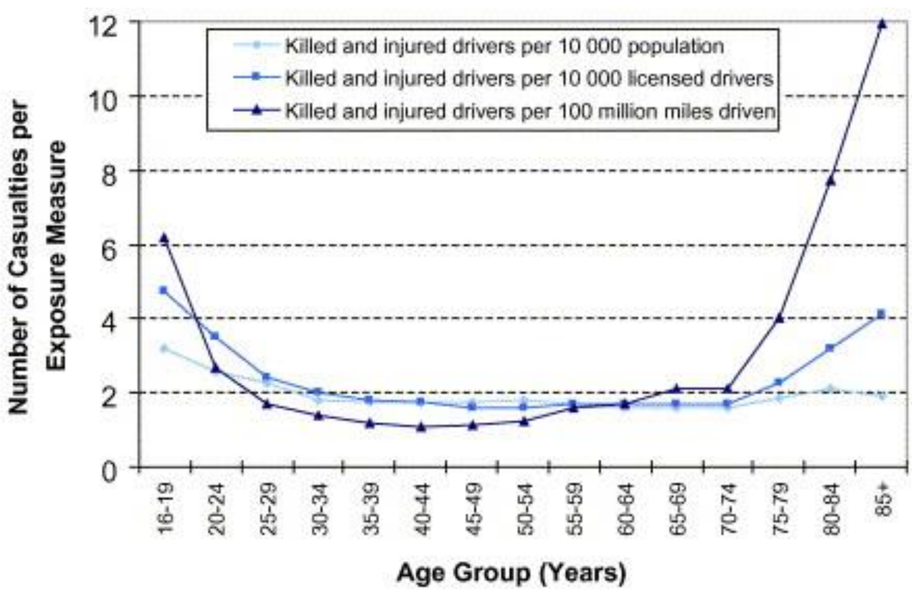

Figure 1 Source: Organisation for Economic Co-operation and Development (OECD). (2001). Ageing and transport: Mobility needs and safety issues. Report published by an OECD Scientific Expert Group, Paris, France.

The need for older driver screening

A major rationale for screening and assessing drivers as they age is that older drivers are more likely to be injured or killed as a result of a crash than most other age groups due to physical frailty [22]. It has been estimated that compared to drivers aged 30 to 59, drivers aged 70 to 74 are twice as likely to die when involved in a car crash and drivers aged 80 years and over were five time as likely to die [23]. Older drivers who are hospitalised due to injury in car crashes have an increased length of stay compared to younger drivers [9]. Thus, older drivers who become involved in a motor vehicle crash can place financial burden on the community in terms of acute healthcare costs and the need for continued care. While it is important that as many older people as possible can continue driving it is also important to ensure that those who are unsafe to drive are identified.

The existing screening measures used to identify unsafe drivers are not always associated with lower driver fatality rates [24]. For example, visual testing is mandatory in many states and cognitive screening is not required. However, evidence has shown that visual tests alone are a poor predictor of driving performance [5]. To accurately predict crashes and unsafe driving both cognitive and visual function need to be tested. Some of the major assessments currently available to screen older drivers include the Useful Field of Vision (UVOF) [25], Hazard Perception Test (HPT) [26], DriveAware/DriveSafe Test [27], Occupational Therapy Driver Off-Road Assessment (OT-DORA) [28], Gross Impairment Screening Battery of General Physical and Mental Abilities (GRIMPS)[29], the Elemental Driving Stimulator (EDS) [30], the California test (CALTEST), and the DriveABLE test [31]. The majority of these screening batteries are time consuming to administer and focus only on specific domains such as: visual attention in a driving context, or speed of reactions, or general cognition. The GRIMPS assesses cognitive abilities that are likely to affect driving performance and has been associated with driving performance, but takes up to 1.5 hours to administer. The EDS comprises a computer-based driving simulator, the participant undertakes six attributes of driving performance including steering control, speed of reaction, field of vision, adjusting, self-control and consistency [30]. The CALTEST is comprised of three components- the Autotrails, the Useful Field of Vision (UFOV), and an adapted version of the Hazard perception test. Finally the DriveABLE test comprises six computer-based tasks which test motor speed, UFOV, complex judgements, attention shifting, executive functions and component driving abilities [32].

Previous studies have evaluated existing screening tests [33, 34]. Findings indicate that none of the measures for the EDS showed a relationship with on-road driving performance [33], and that only particular subtests of the CALTEST and DriveABLE assessments are useful in predicting at-fault motor vehicle crashes, such as the UFOV. For example, a 5-item GRIMPS assessment may be just as effective at identifying high-risk drivers as the full 11-item test [33].

The Multi-D

Over the past decade, Professor Kaarin Anstey and Professor Joanne Wood have developed an evidenced based battery of tests that identifies unsafe older drivers [6, 15, 34]. This novel, multidisciplinary screening battery was developed (Multi-D) from a much larger range of sensorimotor and cognitive tests that were evaluated against performance on a standardized on-road test and prospective history of crashes over 12 months [15]. Unlike existing driver screening tests, the Multi-D is quick and easy to administer (taking around 10 minutes) and includes cognitive, motor and visual components – making it highly relevant and sensitive to age-related changes that may affect driving performance. The rationale and basis for the multi-domain approach to driver screening are documented in previously published papers [5, 15, 34]. The battery tests choice reaction time involving hand and foot responses, visual motion sensitivity, balance and self-reported distance driven. Published initial sensitivity and specificity of the battery was excellent for classifying pass/fail on an on road test of 270 older drivers [15, 17, 35, 36]. Although the focus of the research with the Multi-D has been older drivers, younger or middle-aged adults with neurological or visual disorders that impair abilities measured by this battery will also be identified as unsafe drivers.

Project Objectives

The present project aimed to enable translation of the Multi-D battery into real world application and into further research. The elements of the Multi-D were designed for research projects ten years ago, and there were only two copies of the batteries available - one in the lab of Professor Kaarin Anstey at the ANU, and one in the lab of Professor Joanne Wood at the Queensland University of Technology (QUT). Given the evidence of high sensitivity and specificity of the Multi-D for identifying at risk older drivers [15], and the lack of availability of high quality evidence-based driver screening tools in Australia and internationally [5, 6, 17], it is important that the Multi-D be made available for use in clinical groups, and for use in further research to establish its validity in a variety of driver populations as well as against existing methods of driver screening. Thus, the objective was to develop the hardware and software into a standardised format of clinical quality for driver assessment settings. There are four components to the project:

1. Development of the prototype: this is a detailed technical document that describes the hardware and software so that it can be replicated.
2. Development of 5 copies of the battery. These batteries will be distributed to clinical teams and researchers to enable translation of the tool and further research.
3. Development of a DVD that provides instructions and training in the use of the battery.
4. Development of a standard scoring protocol based on normative data on the battery from the two previous studies that have used the battery.

Intended use

The Multi-D is intended for use as a screening instrument for identifying individuals at risk of unsafe driving and therefore require follow-up with a detailed on-road driving assessment. At present, it is being investigated as a screening battery for use in older driver assessment, including in clinical groups such as older drivers with visual impairment and with cognitive impairment. This trial is being conducted with the participation of local licensing authorities and driver assessment programs. As further data are collected on the Multi-D’s predictive validity and generalization to clinical and international samples, it will represent a solid, evidence-based tool to support clinical decision making regarding older drivers.

Production of the Multi-D

Updating and producing the test components

Dot Motion Test

The Dot Motion Test was developed by QUT Optometry and Vision Science researchers ProfessorJoanne Wood and Dr Philippe Lacherez. The task is designed to estimate the older driver's threshold for identifying the direction of visual motion. Relative to measures of static visual acuity, data from older drivers indicate that sensitivity to dynamic visual displays (i.e., visual motion) is significantly more predictive of on-road driving skill [15, 34]. The test was reprogrammed as a standalone application using open-source platform PsychoPy (http://www.psychopy.org/). The administration instructions and software enable the test to be conducted in a standard manner in any setting and to be installed and run on any contemporary Windows computer.

Postural Sway Test

The postural sway test was developed by researchers at the Falls and Balance Research Group at Neuroscience Research Australia and is commercially available as the PPA Sway path test (http://www.neura.edu.au/apps/ppaswaypath) as of 2012. The test is widely used in assessing falls risk in older adults and was found to significantly predict on road test performance in older drivers [15]. The original version of the postural sway test utilised pen and paper methods of recording the total sway path, however, in recent years an iPad application was developed to use with this simple test. The iPad application enables automatic calculation of the length of the sway trajectory. The Multi-D requires the total path length in order to estimate the final risk scores. The postural sway meter, belt, iPad App, and instructions for use were provided by Neuroscience Research Australia.

Colour Choice Reaction Time

The Colour Choice Reaction Time test was developed by ProfessorKaarin Anstey at CRAHW, ANU and originally programmed by Dr Chris Hatherly in 2006 to be run in MatLAB, a licensed, high-level programming language for data analysis and development of applications. Thus it could not be used without access to the MatLAB program (http://www.mathworks.com). The test also required a response box with two buttons and two pedals for collecting and timing hand and foot responses. This interface was originally designed to work via the parallel printer port of a windows computer. In order to update both the software and hardware, new response boxes were built using Arduino Uno open source micro-controller circuit boards (http://www.arduino.cc) with serial port that could communicate via USB. The original program was modified for use with a serial input device and to be run as a standalone MatLAB application using MatLAB's Compiler Runtime. The resulting updated program can be installed to run on any current Windows OS (in 32-bit or 64-bit).

Instructional Manual and Video

An instructional manual was developed (see Appendix A), documenting the background and intended use of the Multi-D battery, a guide for administering each of the three subtests, normative data based on previous research, as well as the scoring procedure. Instructions for installing and running the computer programs accompanying the test was also developed (see

Appendix B) and are included in an Appendix to the manual. An instructional video was also produced to complement the manual. This video provides step by step instructions for administering each subtest as well as preparing the participant for each test.

Development of a Driving safety risk calculator

In order to ensure ease of scoring for clinician and researcher alike, a Microsoft Excel based driving safety risk calculator was developed. This application uses data from over 300 older drivers that were assessed on the Multi-D as well as assessment of driving behaviours and on-road driving skills [5, 15, 17, 34, 36]. The application allows the clinician or researcher to enter the participant's scores on each of the three tests, as well as their reported weekly driving distance, to obtain a risk associated with the likelihood of being classified as an 'unsafe driver' on a standardised on-road assessment [37]. While this risk score does not imply that the participant *will* have a crash under that participants' natural driving conditions, the score indicates the likelihood that participant will fail an on-road assessment. This composite risk score is likely to be valuable evidence for referring individuals for further assessment and intervention in the clinical setting. As further research data on the Multi-D is collected, this will be included in the data set for deriving predicted risk from the composite Multi-D score – providing a more accurate and reliable risk score. The scoring application also allows the examiner to obtain percentile scores for each of the three component tests in the Multi-D battery. These values can indicate whether the participants' estimated driving risk is particularly influenced by poor performance on a single test. This can inform the clinician about areas of functioning that may require particular attention in follow-up assessments of that participant.

Translation to Clinical Assessment

An evaluation of how well brief screening instruments can classify safe and unsafe older adult drivers – Funded by the National Health and Medical Research Council (2012-2017)

Of the five test kits produced, two will be used as part of a large, multi-site validation study examining the predictive validity of several commonly used driver screening instruments, as well as the Multi-D. The other tests to be examined include the UFOV [25], the Hazard Perception Test [16, 26, 38], the DriveAware/DriveSafe Test [27], and the OT-DORA (www.aota.org) [28]. These instruments represent tests that are currently used by Transport Departments around Australia (e.g., Hazard Perception Test) and internationally (e.g., the UFOV) as well as by Australian clinicians making decisions about driving safety in older adults (DriveAware/DriveSafe and OT-DORA). The study involves local driver assessment and licensing agencies – such as the Driver Assessment and Rehabilitation Service (DARS) of the ACT Health Directorate, and the ACT Traffic and Municipal Services (TAMS). The study will be conducted on 650 individuals across two sites (ACT and Queensland) and will investigate the validity of the off-road tests relative to a standardised on-road driving assessment protocol [37]. The participants will also be followed-up over a period of two years, with monthly self-reported traffic incidents and other measures of driving. Participants will include two clinical samples (those referred to a vision clinic, and those referred for further assessment due to cognitive or other medical reasons) as well as community based samples.

During the course of the study, researchers will regularly communicate with DARS and TAMS personnel about current practice, study progress and outcomes, as well as provide practical demonstrations on the administration and use of the Multi-D and other off-road instruments. The outcomes from the study have significant implications for practice. The findings will inform traffic authorities and clinicians about the most sensitive instruments for identifying at-risk older drivers in the Australian context, their ability to predict long-term driver behaviour, and their applicability in different populations: healthy, cognitively impaired and visually impaired older adults.

Translation across research fields

Two of the Multi-D kits produced will be used in external research projects examining high-risk drivers, and cognitive interventions for older adults. This will ensure continued data collection on the Multi-D in international driving contexts as well as in the context of general mobility and cognition in older adults.

A naturalistic driving study across the lifespan – Funded by the Southeastern Transportation Research, Innovation, Development and Education Center (STRIDE) and the Alabama Department of Transportation, U.S.A

Dr Lesley Ross and Dr Despina Stavrinos at the University of Alabama, Birmingham in the United States are using the Multi-D in a study of naturalistic driving behaviours in two at-risk age groups of drivers – those aged between 16 and 19 years and those aged above 65 years. Using GPS and video data, participants' driving skills will be measured and compared with their performance on cognitive, physical, psychological and sensory tests (see Figure 2). Approximately 100 participants are expected to complete participation in this detailed study.

The main aim of the study is to make a detailed study of driving behaviour in two high risk age groups with the use of naturalistic driving technologies. The study will collect data on real-world driving mobility (amount traveled throughout environment), driving safety (crashes/risky driving behavior), and driving behavior (how/when travel occurred) in the two high risk age groups. Each participant's vehicle will be fitted with small GPS and GIS (Global Information Systems; Porter et al., 2002) as well as DriveCam Event recorders (www.drivecam.com). These systems will enable the collection of detailed, naturalistic data on driver identity (via an inconspicuous wide-angled camera), driver behaviour, driving conditions and route. Information about trip conditions (e.g., speed, traffic, weather, time of day) will be recorded, as well as critically important traffic environment related variables and actual unsafe driving behaviors. All participants will be assessed at baseline for cognitive, sensory, and physical/health functioning – which includes the Multi-D. Then, each participant’s vehicle will be installed with (1) an event-triggered video recording system (DriveCam Event recorder) providing information about high g-force events (i.e., MVCs, near MVCs, and critical incidents as well as distracted driving occurrences) and (2) a GPS and GIS (Global Information Systems) device providing detailed data regarding the trip, speed, traffic, weather, time of day, and traffic surrounding the driver. Data will be collected over a period of two weeks. Participants will then return for a post-test assessment (including detailed self-report driving questionnaires) and for removal of the devices.

It is hypothesized that there will be a low correlation between commonly used self-reported measures of driving and newer, objective measures (GPS/GIS and in vehicle monitoring devices). Importantly, the study will also objectively measure distracted driving in older adults, and data will be available on the association between Multi-D scores and distracted driving in a natural setting. The study will also enable the collection of Multi-D data in a young high-risk group of drivers and its association with real-world distracted driving. Study results will be valuable to various stakeholders including: researchers (dissemination of results/suggestions for areas of needed research), medical community (realistic idea of actual driving and how it relates to self-reported driving), and potential policymakers (actual amount of distracted driving in at-risk age groups and how it relates to driving safety).

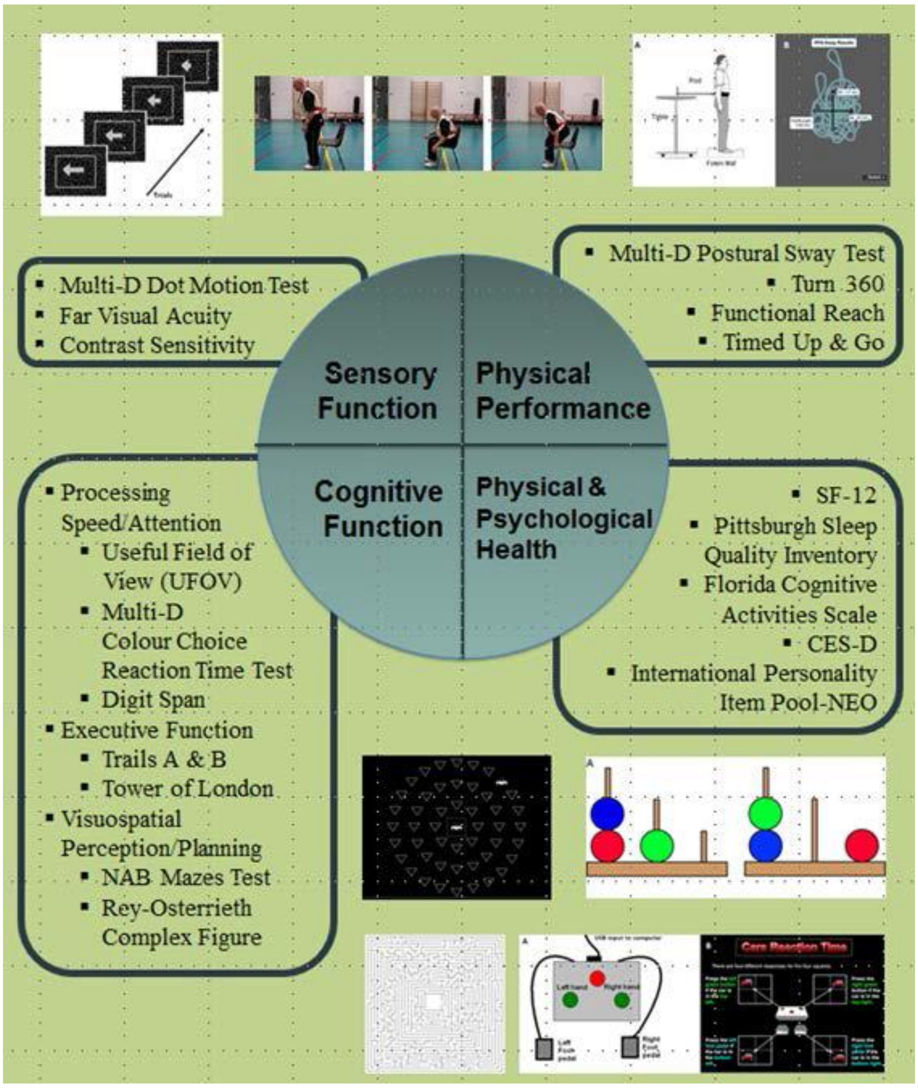

Figure 2 Source: Senior and Adolescent Naturalistic Driving Study (SANDS) – project protocol posted on STRIDE site: http://www.stride.ce.ufl.edu/current-projects

The Dancing Mind: cognitive benefits of multi-dimensional physical activity in old age – Funded by the Illawarra Retirement Trust Research Foundation (2013-2014)

Associate Professor Dafna Merom at the University of Western Sydney is using the Multi-D as one of the measures in a 6-month randomised controlled trial (RCT) of social dancing as an intervention for age-related cognitive and physical decline [39]. With the projected increase in the global population of older adults, and concomitant rise in the prevalence of dementia and other age-related cognitive problems, there is greater public interest in interventions that can offset this cognitive decline. Epidemiological and clinical studies suggest that physical activity is associated with better cognitive health and reduced risk of dementia [40]. Randomised controlled trials have also demonstrated that exercise programs can improve cognitive functioning in older adults with or without pre-existing cognitive decline [41]. Independently, social interaction is also known to be protective against cognitive decline and dementia. Dancing is a complex sensorimotor activity that combines cognitive, physical, social and affective dimensions. Thus it is expected that a program of learning and participating in social dance will simultaneously engage multiple protective factors against cognitive decline: (1) cognitive activity (through learning, sequencing and coordinating movements), (2) physical activity (aerobic fitness and balance) and (3) social engagement (interaction with dance partner and other dancers).

The project aims to recruit 120 participants over the age of 65 years from Sydney retirement villages. Participants will be randomised into two groups – a 6-month home-based walking program (Control Group), and a 6-month Social Dancing program. All participants will receive cognitive and fitness assessments at baseline, immediately after intervention and at a

6-month follow-up. The Multi-D is included in the baseline, post-intervention and follow-up testing protocol. It is hypothesised that the Social Dancing program will confer greater cognitive change relative to the active Control group. If successful, the study will provide evidence not only for social dance as a viable and effective cognitive intervention for older adults, but will also further the evidence-base for the Multi-D as a tool that is sensitive to changes induced by short-term intervention programs.

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Appendix A

The User Manual

The Multi-D
Driver Screening Battery

Test Manual

Kaarin Anstey PhD & Joanne Wood PhD

Acknowledgements

The production of the Multi-D Test Battery was funded by a project grant awarded to K. Anstey by the NRMA – ACT Road Safety Trust. Research and development into the Multi-D was funded through research grants awarded to K Anstey and J Wood by the National Health and Medical Research Council of Australia, the NRMA – ACT Road Safety Trust and the Australian Research Council. C Hatherly, P Lacherez, L Jenkins O'Donoghue and R Eramudugolla assisted in preparing the test manual and technical development of the tests and scoring protocol.

Contents

Introduction

Development of the Multi-D

The Multi-D was developed on the basis of the Multifactorial Model of Driving Safety [1]. This model identifies the contribution of cognitive (e.g. processing speed, executive function and working memory), sensory (e.g. peripheral vision, contrast sensitivity and motion perception) and motor factors as influences on driving skill. The model separates "capacity to drive safely" from "driving behaviours" [1]. The model suggests that cognitive, sensory and physical variables determine an individual's capacity to drive, but individual's insight into driving behaviour (self-monitoring) influences the choices that individuals' make about driving and therefore their driving safety [2]. For example, older drivers might decide to not drive at night or in poor weather conditions, or to only do trips which are short or familiar [3]. In other words, both driving skill and self-monitoring of behavior influences the capacity to drive safely.

The methodology for developing the Multi-D was based on a study which included a wide range of potential sensory, cognitive and motor variables [4]. These variables were based on knowledge of which abilities demonstrate age-related declines and, either demonstrably or hypothetically, affects driving capacity. Consistent with the Multifactorial Model, the final selection of tests based on their association with performance on an on-road driving test, includes measures from the three key functional domains (sensory, cognitive and motor). The optimal combination of tests was chosen to create the Multi-D screening battery with 91% sensitivity and 70% specificity in classifying participants according to whether they failed on a standard on-road driving test.

Purpose of the Multi-D

The Multi-D is an off-road screening battery that is intended to identify older adults who may be unsafe to drive or at increased risk. In its present form the screening battery is intended for research use only until further studies assess its predictive validity against on-road driving ability and long-term driving behaviours. Once validated, the Multi-D will be made available for clinical use purely as a risk assessment and screening tool which may identify 'at risk' drivers and help target resources for assessment, rehabilitation and intervention. The Multi-D tests abilities that have been linked to specific types of on-road errors however, it cannot be used to base licensing decisions. It is intended to identify older drivers who may need further assessment of driving capacity before making licensing decisions.

Although the focus of research has been older drivers, specifically above 70 years of age, the Multi-D can also be used to screen driving capacity in younger or middle-aged adults with neurological or visual disorders, and future research will need to validate the tool in these groups.

Examiner qualifications

The Multi-D can be administered by anyone who is familiar with the Multi-D administration and scoring procedures. Examiners must be aware that the Multi-D is a screening tool only, and in its present form only for use in research. In order to classify drivers as safe or unsafe for the purpose of licensing decisions, further assessment is required.

Instructions for Administration

Introduction

The components of the Multi-D do not need to be administered in any particular order. The Dot Motion task takes approximately three minutes. The Postural Sway task takes approximately two minutes and the Colour Choice Reaction Time task takes approximately five minutes. Thus, in total the Multi-D should take approximately ten minutes to administer.

Administration of the Multi-D should take place in a moderate sized room which contains a table, chair, and a computer. The room needs to be free of distractions, such as background noise or other people, as participants are required to focus on tasks. Administrators will require the Multi-D set, which contains the Swaymeter and Colour Choice Reaction Time response box and foot pedals. All equipment should be installed and ready to use before the participant arrives. Please refer to the Appendix for the Installation Guide.

Distance Driven per week

The participant should be asked the following question:

How many kilometres would you drive per week?

Option:	**1**	**2**	**3**	**4**	**5**	**6**
Kilometres	**<10**	**10 to 30**	**31 – 60**	**61 to 100**	**101 to 150**	**>150**
Miles	**<6**	**6 to 18**	**19 to 37**	**38 to 62**	**63 to 93**	**>93**

Record their answer as a number between 1 and 6 representing their choice of options 1 to 6 and enter this number in the Multi-D Scoring spread sheet.

Dot Motion Test

The Dot Motion sub-test of the Multi-D assesses the older person's visual sensitivity to moving stimuli. This sub-test uses computer-generated random dot kinematograms which consist of a dense pattern of randomly arranged black and white dots (or visual noise) that is displaced coherently in one direction or the other (see Figure 1). The density of the random dots prevent observers from tracking the trajectory of individual dots and hence rely on 'global' motion processing mechanisms that integrate local motion information– an aspect of visual processing that is selectively impaired in age-related visual decline [5]. Importantly, visual motion perception is also a significant predictor of driving ability in older adults [4].

The Dot Motion sub-test involves viewing a random dot display on a computer screen as in Figure 1. The main display contains incoherent or randomly moving dots, while a central region of dots within this main display move coherently in one direction. A proportion of dots within the central region undergo a constant displacement in a uniform direction. The direction and the amount of displacement of the dots within the central region is varied successively over multiple trials such that initially the direction of motion is easily detected (large displacement) and becomes increasingly difficult to determine (small displacement). The minimum displacement threshold (**D_{min}**) is the smallest displacement for which the individual can reliably determine the direction of motion [6]. The threshold displacement $\mathbf{D_{min}}$ is expressed as log of visual angle. Note that higher thresholds indicate poorer sensitivity to motion.

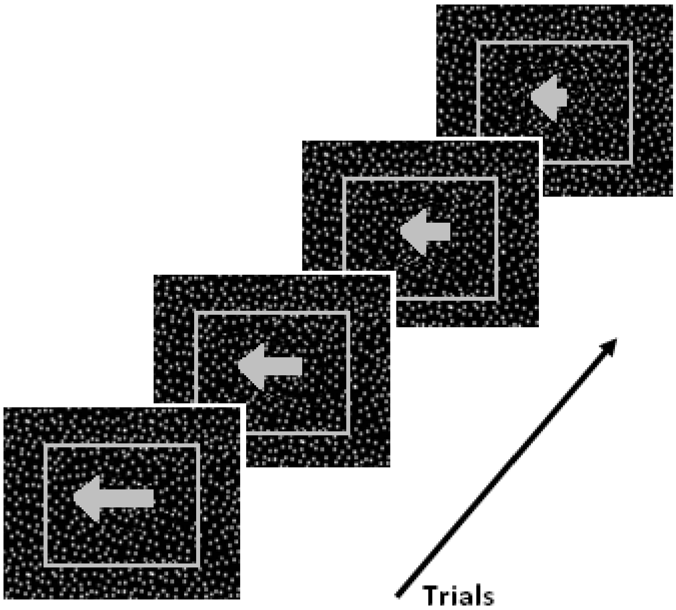


Figure 1. *Stimuli used in the Dot Motion subtest*. Random dot kinematogram with a central region of dots embedded within a larger homogenous field of dots. Dots move discretely in four successive steps. The grey border and arrows are shown here only for purpose of illustration.

Equipment Required:

- Computer with Dot Motion program installed

Instructions:

Seat participant directly facing the computer (**3.2 metres** away). Participants should wear their appropriate distance vision correction, as a fixed single-vision lens (not multifocal). The room should be dark, or with a very low level dimmer.

Start up the Dot motion program. A splash screen will appear as shown in Figure 2.

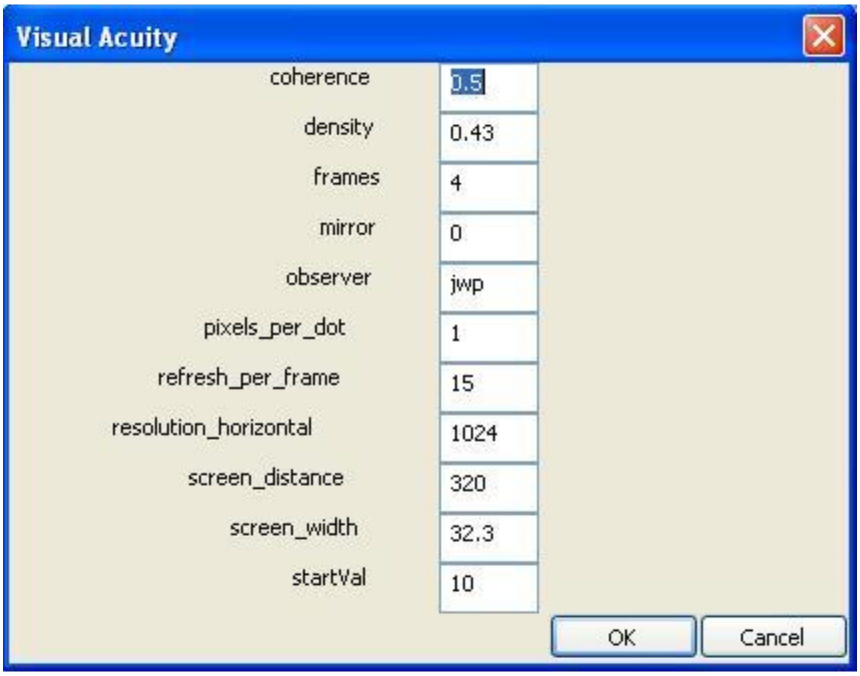


Figure 2. *Start-up splash screen for Dot Motion Test*.

Please note the settings and adhere to them. If the monitor for the computer on which the test is to be run does not support a horizontal resolution of 1024 pixels, this value may need to be changed, however for fully accurate testing the resolution should be as close as possible to 1024. The screen width should also be changed if necessary – it should correspond to the width of the glass/pyrex part of the screen in centimeters. The screen distance (320) refers to the distance of the participant from the screen in centimeters. Input the unique identifier for the participant into the observer field. Click OK.

Give the participant the following instructions:

"Now in this test, you will see a square of dots on the screen. A section of these will move either, down, left or right. It will never move at an angle, only in one of those directions."

"All you have to do is to say which direction the section moves. Even if you are not sure, just have a guess, as you will most probably get it correct. It is worth having a guess as this test is sometimes intuitive, and you will be surprised how much you pick up even when you don't think you really have much of an idea!"

"So remember to have a guess even if you aren't really sure, and that it is a threshold test. This means that the test will gradually get harder (it is meant to), as the computer is trying to work out at what level you can see the block move."

Run the test. After each presentation the program waits for a keyboard input. The participant should be instructed to answer out loud, and the experimenter should enter the response via the arrow keys of the keyboard. At the end a black screen will appear with a number (usually a negative number like -2.66556 etc). This is the participant's threshold score in log deg arc. Record this value. The value will be entered into the **Multi-D Scoring spread sheet**.

Staircases and psychometric function fitting:

This version of the Dot Motion Test includes a feature that allows the examiner to look at the staircase and psychometric function in order to identify how reliably the threshold estimate was calculated. Figure 3 displays two graphs that provide this information, and will appear at the end of the test.

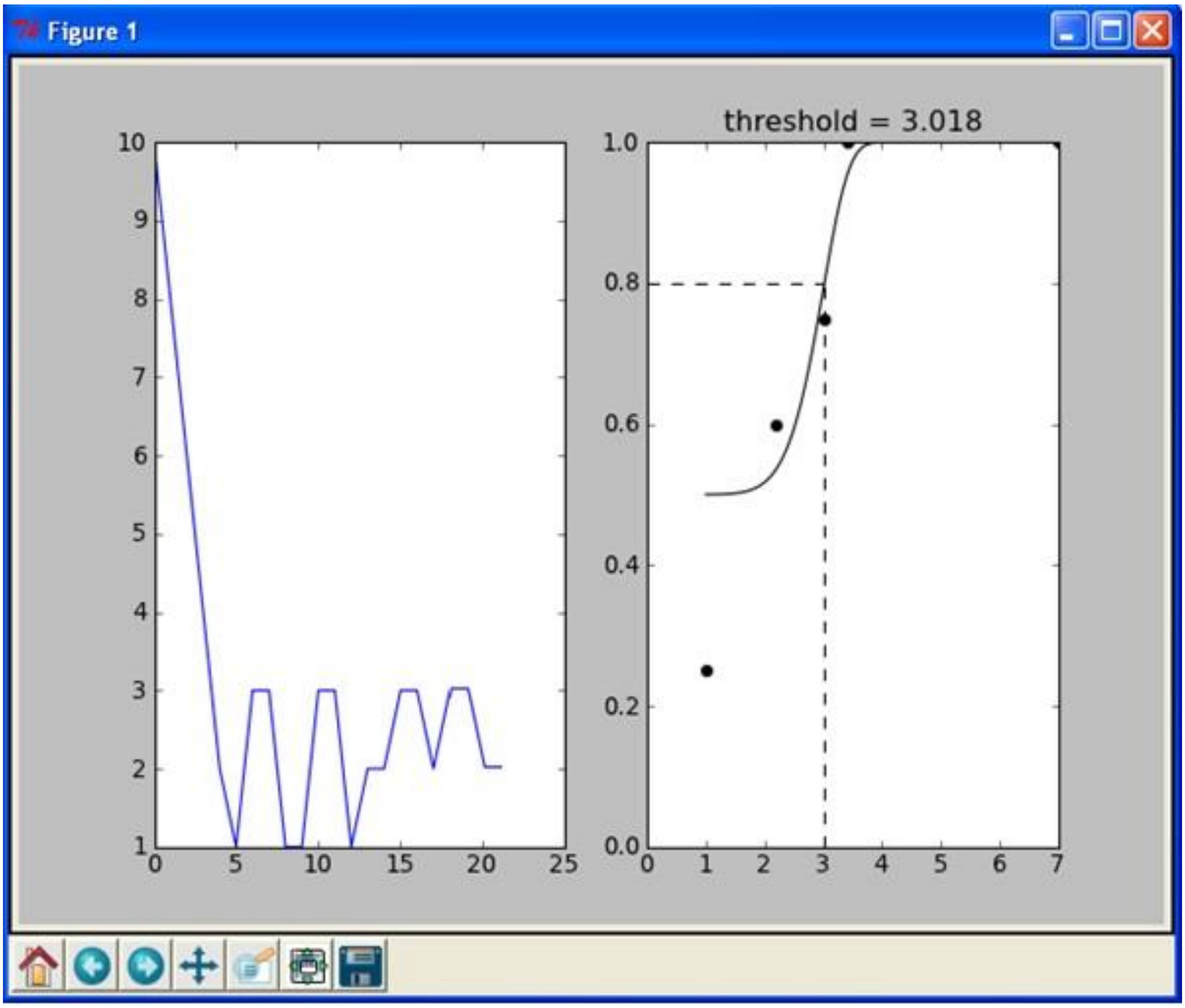


Figure 3. *Psychometric Function for the Dot Motion Test*.

The graph on the left panel of Figure 3 is a plot of trial number on the X-axis against signal strength on the Y-axis. Here, signal strength refers to the magnitude of dot motion, so 1 indicates the dots moved 1 pixel, and 10 means the dots moved 10 pixels. The test uses a 'staircase procedure' to reduce the signal strength (and thereby increase the difficulty of a trial) whenever the participant responds correctly for two sequential trials. Similarly, the staircase procedure makes the next trial easier if the participant responds incorrectly on one trial. This method allows the program to converge on the minimum signal strength required for the participant to correctly identify motion direction – or in other words, the threshold estimate. Figure 4 displays some example staircases. A good staircase should demonstrate convergence towards the final threshold estimate. Figure 4A and B are examples of successful staircase procedures. Note that at the end the value oscillates around a narrow value (converges). If the staircase continues to descend or ascends without stabilizing at the end (see Figure 4C), this suggests the final value is not a reliable estimate of the threshold and the test should be re-run.

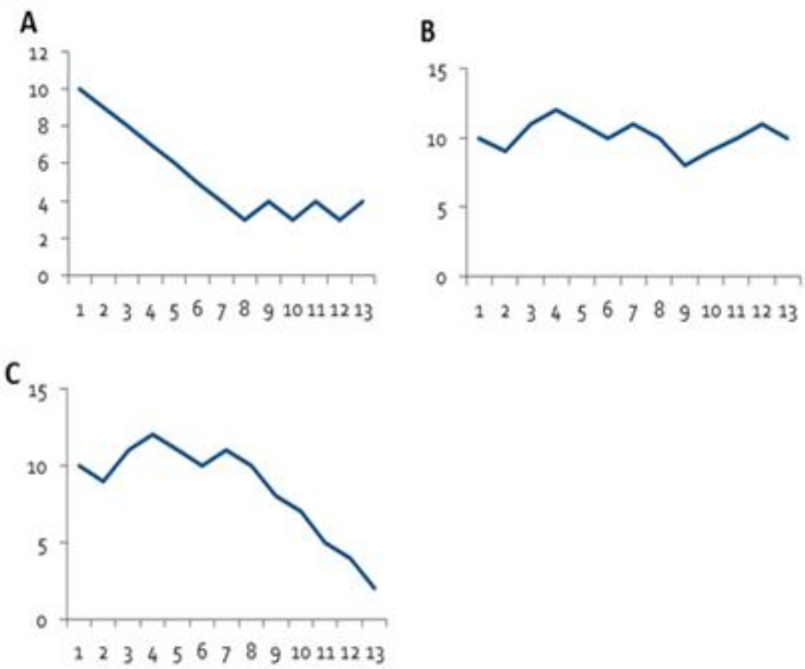


Figure 4 *Psychometric Function for the Dot Motion Test*. **(A)-(C)** psychometric function showing convergence of estimates towards participant's threshold level of motion perception. **(D)** psychometric function showing continuing decline in estimate before test is terminated.

The second plot on the right panel of Figure 3 is a 'psychometric function'. This is a plot of signal strength against accuracy. The curve of best fit, which is superimposed upon it, should resemble an

S-shape. This provides a secondary check that the test has successfully estimated the threshold for motion detection, and it is not unusual for this to look very different from an S-shape, so this plot may be disregarded providing the staircase has converged appropriately.

Postural Sway Test

Age-related declines in lower limb strength, coordination and proprioception (sense of position and movement of body parts) can be caused by a variety of acute and chronic medical conditions in old age and can significantly impact on mobility and complex motor activities. The ability to maintain balance while standing is dependent on multiple motor and sensory functions, including limb strength, coordination and proprioception, providing a sensitive measure of sensorimotor integrity in older adults. The Postural Sway test, taken from the Physiological Profile Assessment, is predictive of falls risk [7] as well as driving ability [4] .

Postural sway is measured using a Swaymeter that measures displacement of the body at waist level. The device is low-tech and simple consisting of a 40cm long rod with a vertically mounted pen at its end. The pen is positioned on a graph paper fasted to a table behind the participant. The participant is required to stand as still as possible for 30 seconds on a soft surface (medium-density foam rubber mat) with their eyes closed. The magnitude and frequency of postural adjustments to maintain balance are recorded on the graph paper. The lack of visual feedback to maintain balance and the soft surface make this simple task more difficult and hence more sensitive to age-related changes. Neuroscience Research Australia has developed a postural sway application (PPA Sway App) which can be downloaded onto an Apple iPad.

Equipment Required:

- Postural Swaymeter (40cm rod attached to belt)
- Table
- Medium density foam mat (40 cm x 40cm x 15 cm)
- Stop-watch or timer
- iPad with iOS 5.0 or later
- Capacitive touch screen stylus
- PPA Sway Path App
- Blocks for adjusting height of the iPad

Ensure that the stylus holder is attached to the Swaymeter. Attach the touch screen stylus to the end of the 40cm rod, secure into place by tightening the screw.

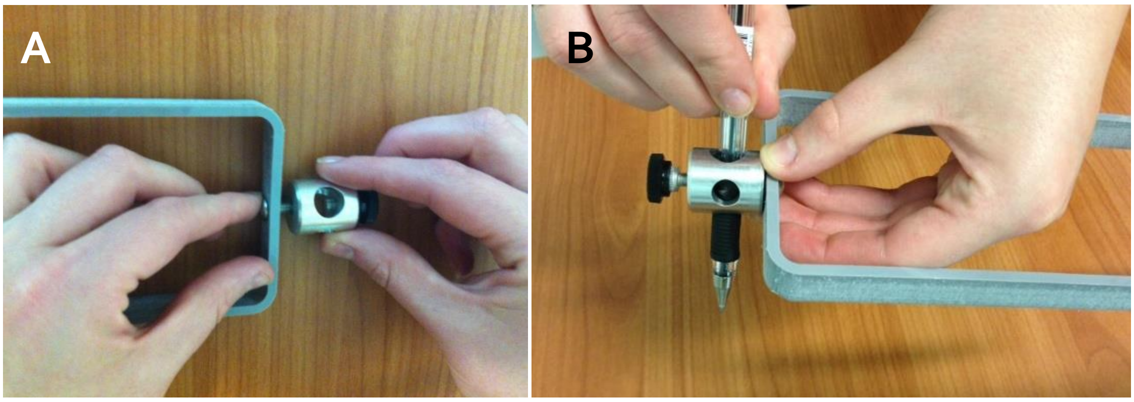


Figure 6. (A) *Set-up for stylus holder:* Stylus holder is attached to rod by screw inserted into the hole and tightened **(B)** *Example of stylus in holder:* Insert a stylus into the holder, secure into place by tightening the black screw.

Start the PPA Sway App and on the main screen, select the appropriate version of the test - **On foam - eyes closed** from the four options available. If the participant requires a preliminary practice trial, the examiner may select one of the other less demanding versions of the test as needed before proceeding to the version required for the Multi-D.

Surface	**Visual cues**	**No visual cues**
Firm (stable)	On floor – eyes open	On floor – eyes closed
Soft (unstable)	On foam – eyes open	**On foam – eyes closed**

Enter the Participant ID and press Start.

A black screen will appear with a white cross located at the center of the screen. The cross indicates the starting point for the sway path measurement.

Say to the participant:

"For this task we are going to measure your postural sway. We are going to wrap a belt around you, which is attached to a rod. For this task you will need to keep your eyes closed and stand as still as possible for 30 seconds."

"Please remove your shoes".

Snugly fit the belt (attached to the rod) at the level of the participant's anterior superior iliac spine. The Swaymeter is placed posterior to the subject so that the influence of vision is also excluded. The iPad is placed behind the participant and is secured to prevent displacement during the measurement.

"Please stand on the foam mat". The subjects feet should be positioned 10cm apart.

Ensure that the iPad is levelled in such a way that the rod of the Swaymeter is maintained in horizontal position.

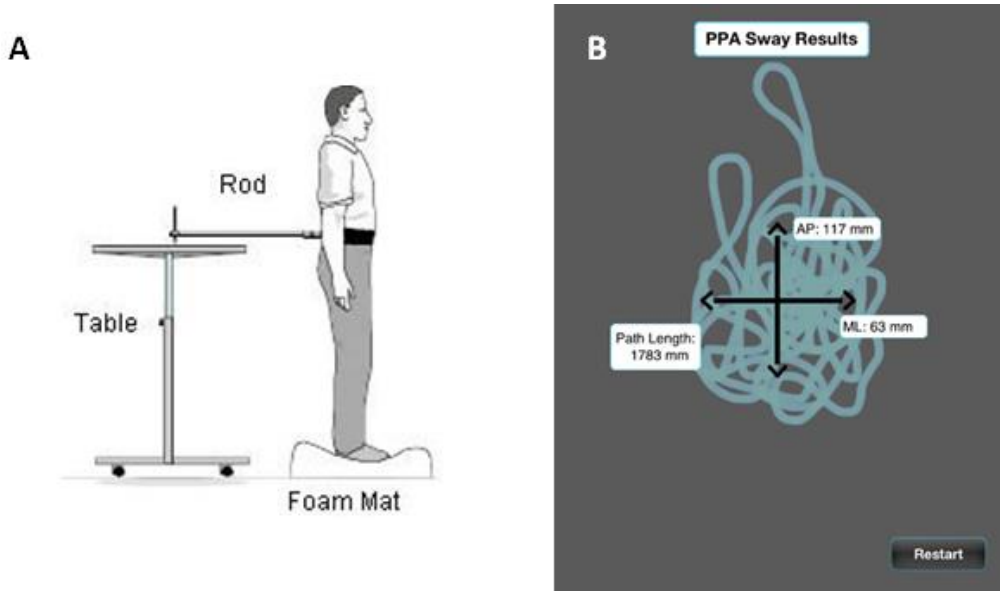


Figure 7. (A) *Set-up for the Postural Sway sub-test:* The rod and pen are fastened to the participant's waist and extends posteriorly to the height-adjustable table. The participant stands on the medium density (15cm thick) foam mat with their eyes closed. **(B)** *Example results of postural sway and measurements from PPA Sway Path App.*

Say to the participant:

"Please place your hands by your side and close your eyes." Place the stylus on the starting point indicated on the screen (the white cross) while the stylus is attached to the Swaymeter. Stand nearby the participant to help steady them if they become unbalanced and to prevent them from falling.

"I want you to stand as still as possible for 30 seconds, starting now. I will say 'stop' when the 30 seconds is up."

If the stylus lifts off the iPad screen, the app will prompt you to replace or restart the test. Signal to the participant the end of 30 seconds, but ask them to stay in the same position. Take the rod of the Swaymeter away from the iPad. Follow the prompts to conclude the measurement.

Record the Path Length that appears on the screen (Figure 7B). In addition to the path length, the app will also provide the magnitude of directional sway – Anterior-Posterior (AP) and Medial-Lateral (ML). The PPA sway app also provides some general normative data based on the total path length to compare the participant's results if desired. This is separate from the Multi-D battery scores.

Say to the participant:

"I am now going to give you 5 to 10 seconds of rest, and then we will do that once more. Please do not move from your current position"

After 5 to 10 seconds place the rod of the Swaymeter back on the iPad. Ensure that the participant's hands are still by their side, feet 10cms apart and eyes closed. Restart the application for a second trial and place the stylus on the starting point indicated on the iPad as before.

"As you did before I want you to stand as still as possible for 30 seconds, starting now. I will say 'stop' when the 30 seconds is up."

Signal to the participant that the 30 seconds is up and that is the conclusion of the assessment. Record the Path Length for the second trial. This value should be recorded and entered into the **Multi-D Scoring spread sheet.** Remove the belt from the participant and allow them to place their footwear back on.

Colour Choice Reaction Time Test

The Colour Choice Reaction Time sub-test integrates cognitive processes required for driving such as attention, vigilance, divided attention, and response inhibition. Importantly, the test requires participants to make a speeded response with either hands or feet – as is the case during driving.

The subtest requires the participant to respond to a coloured image of a car. The car can appear in one of four locations on the screen that correspond to the limb used to make the response. Participants are instructed to always response to a red car, but to withhold responses to a blue car. Mean reaction time (RT) and error rate and recorded as measures of choice reaction time and response inhibition.

The task takes about 5 minutes to administer (assuming RT less than 1 second). There are 60 trials presented for each test – with a 25% probability of a blue car occurring (withhold response) in the test. Thus, there are 45 responses to red cars and 15 non-responses to blue cars.

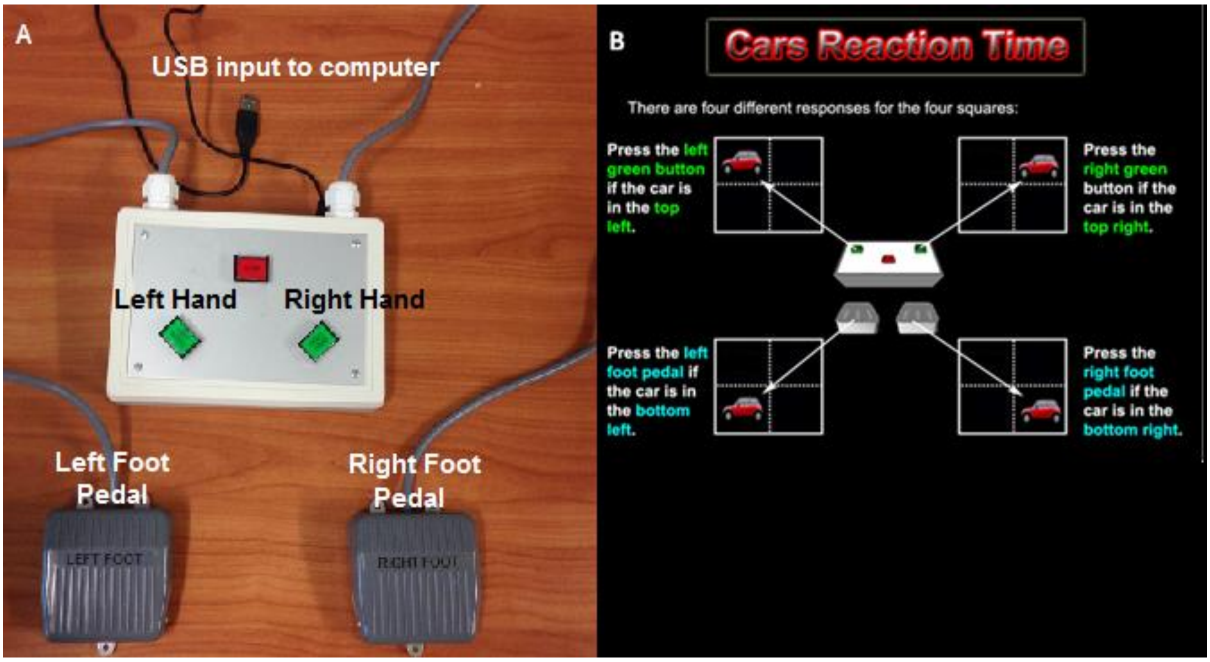


Figure 8. *Colour Choice Reaction Time Test*: **(A)** The response box with response buttons for the left and right hand and pedals for the left and right foot. **(B)** Instruction screen showing the mapping between stimulus location on the screen and the valid response button.

Equipment required:

- Computer
- Colour Choice Reaction Time Test program (CD with folder named “RTCar”) installed
- Response box and foot pedals

To Run Colour Choice Reaction Time Test:

1. Click on ctb.exe (located in the folder appropriate for the OS of your computer)
2. Enter participant details into the dialogue box, Test session.
3. Select CarsRT Test.
4. Leave Practice unticked as the task will always commence with 9 practice trials to help introduce the task to the participant and to familiarise them with the response buttons.

Instructions

Place response box in front of participant, and lay pedals out at their feet. Allow participant to arrange pedals so that it is comfortable for them to press with their feet.

> *“For this task you will be responding to pictures of cars appearing on the screen. Please press START.”*

(Read the following instructions as it appears on the screen)

> *“For this task, you will be responding to a red car on the screen. Press CONTINUE.*
>
> *The red car can appear at four possible locations on the screen. Press CONTINUE.*
>
> *There are four different responses for the four squares. Press the left green button if the car appears in the top left corner. Press the right green button if the car appears in the top right corner.*
>
> *Press the left foot pedal if the car is in the bottom left corner. Press the right foot pedal if the car is in the bottom right corner. Press CONTINUE.*
>
> *Sometimes a blue car will appear on the screen. Do NOT press anything if you see the blue car. Respond ONLY to the red car. Press START for some practice trials.*

Allow the participant time to finish the practice trials. After the practice session, prepare the participant for the test session:

> *"The cars reaction time test will last several minutes. Remember, if you see the blue car, try not to press anything. Do you understand what you need to do? Press START when you are ready to begin."*

Allow the participant time to finish the test.

Once the test is complete, the participant's data will appear in two spread sheets. The spreadsheet named TestsComplete.xls will provide a list of the participants, tests completed and assessment dates (Figure 9A). Note that the participant's data will appear in the row of the spreadsheet that is the participants ID number. The CarsRT.xls file will contain data on each participant's performance, overall accuracy and Mean RT and SD as well as data for each trial (Figure 9B).

A

	A	B	C	D	E	F	G
1	PP	Initials	Gender	Session	Date/Time	CarsRT Simple	CarsRT
2	1	RE	2	2	3/07/2012 16:10	0	1
3							
4							
5							
6							
7							
8							

B

	A	B	C	D	E	F	G	H	I	J	K	L
1	PP	Initials	Total Correct	RedCorrect	RedMistake	RedMissed	BlueCorrect	HandCorrect	FootCorrect	CleanRT	CleanSD	CleanHand
2	1	RE	58	45	0	0	13	30	28	0.8007	0.2411	0.84
3												
4												
5												
6												
7												
8												

Figure 9. *Output data files for Colour Choice Reaction Time Test*: **(A)** *TestsCompleted.xls*. Overall assessment and participant information **(B)** *CarsRT.xls* Performance data including summary results and individual trial for a participant with ID# 1, initials RE.

The Mean RT can be obtained from the CarsRT spreadsheet ("CleanRT") and this is entered into the **Multi-D Scoring spread sheet**.

Guide to Scoring

Dot Motion Test

Once the participant has finished the random dot motion task their score appears on the screen. The score should be recorded and entered into the **Multi-D Scoring spread sheet.** The minimum displacement that can be detected is referred to as the minimum displacement threshold ($\mathbf{D}_{min}$).

Postural Sway Test

The Path Length measure provided by the PPA Sway path app is taken for two consecutive trials. The maximum path length of the two trials is take for analysis. Participants who are unable to maintain balance for the duration of the trial can be allocated scores 2 standard deviations above the group mean or the mean sway path length for the normative group as reported by Wood et al (Mean = 447.98mm (SD=162.23)) [4].

Colour Choice Reaction Time Test

The Colour Choice Reaction Time Test will record participant's reaction time to each trial as well as summary data for the test overall. Data for the test is saved in TestsCompleted.xls and in CarsRT.xls (see Table below). For each trial (Stimulus 1 to Stimulus 60) the participant's response accuracy (e.g. Answer 1, Answer 2) and reaction time (e.g. RT1, RT 2) is saved within CarsRT.xls. The position of the stimulus (e.g. StimPos1, StimPos2) is also recorded and the summary statistics, mean and standard deviation (SD) of response times are presented [4].

Below is a list of the type of information recorded in the CarsRT spreadsheet. The Mean RT for Correct Trials (Clean RT) is used to input into the **Multi-D Scoring spread sheet**.

Data Column	Description
PP	Participant ID
Initials	Participant Initials
Total Correct	Total number of correct trials (max = 60)
RedCorrect	Number of Red Car trials correct
RedMistake	Number of incorrect responses to Red Car trials
RedMissed	Number of missed responses to Red Car trials
BlueCorrect	Number of correctly inhibited Blue Car trials (max = 15)
HandCorrect	Number of correct Hand responses
FootCorrect	Number of correct Foot responses
CleanRT	Mean RT
CleanSD	Standard Deviation of RT
CleanHandRT	Mean RT for Hand responses
CleanHandSD	Standard Deviation of RT for Hand responses
CleanFootRT	Mean RT for Foot responses
CleanFootSD	Standard Deviation of RT for Foot responses
Stimulus1	Colour of stimulus on Trial 1 (Red/Blue)
StimPos1	Location of stimulus on Trial 1 (TL, TR, BL, BR)
Answer1	Correct or incorrect for Trial 1
RT1	Reaction Time for Trial 1
Stimulus2	Colour of stimulus on Trial 2 (Red/Blue)
StimPos2	Location of stimulus on Trial 2 (TL, TR, BL, BR)
Answer2	Correct or incorrect for Trial 2
RT2	Reaction Time for Trial 2

Guide to Interpretation

The **Multi-D Scoring spread sheet** is an Excel workbook which enables the examiner to enter participant's scores and obtain a predicted probability of a dangerous driver score on the on-road assessment. It is suggested that participants scoring in the top 15-20% (i.e. with a risk of 80% or above) should be referred for further assessment.

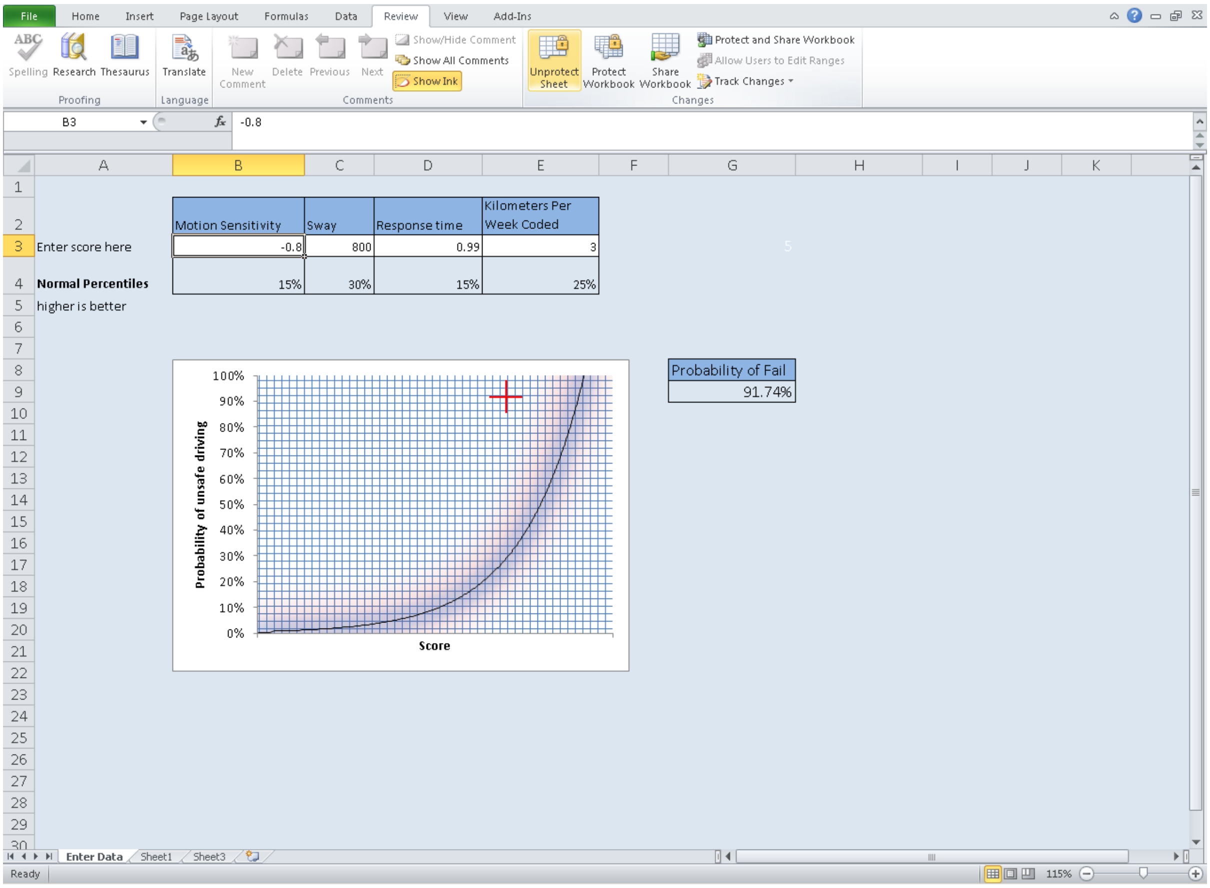


Figure 10. *The Multi-D Scoring spread sheet.* An example set of data indicating a risk of 91.74%

To use the spread sheet, simply enter the participant's scores in the space under each variable name (Motion Sensitivity, Sway, Response time, Kilometres per week). The plot will be updated to represent the participant's score on the assessment battery, with the Y-axis representing the probability of a dangerous driver rating. The red cross represents the current participant's score. The probability is shown in the box beside the plot. The participant's score is also compared against normal percentiles for each test (shown directly below where the value is entered). If the participant's overall probability of fail is high the percentiles may help to show which test (or tests) the participant has performed particularly poorly on. Percentile ranks are represented in terms of increasing levels of performance, so that percentiles lower than 5% can be considered impaired. Note however that unless the 'probability of fail' is high, low performance on one test is likely not predictive of driving safety. Note also that the norms are only applicable to older drivers aged 70+ years. Until further research is conducted, it is not known how these scores should be referenced for younger adults.

Normative Data

It is important to recognize that higher or lower scores on any single measure are not in themselves indicative of increased risk of poor driving. Very abnormal scores on any single measure may indicate a functional impairment, but it is necessary to examine all scores together to establish whether the patient is at risk of poor driving.

		Mean	**Standard Deviation**
Dot motion (logMinArc)	Age 70-74	-.70	(.21)
	75-79	-.67	(.22)
	80-84	-.51	(.20)
	85+	-.08	(.51)
Sway path length -- eyes closed on foam	Age 70-74	420.26	(135.92)
	75-79	489.68	(187.30)
	80-84	584.95	(183.15)
	85+	863.00	(34.00)
Colour choice reaction time (sec)	Age 70-74	.78	(.11)
	75-79	.78	(.09)
	80-84	.88	(.16)
	85+	.96	(.18)

References

1. Anstey, K.J., et al., *Cogntiive, sensory and physical factors enabling driving safety in older adults.* Clinical Psychology Review, 2005. **25**: p. 45-65.
2. Horswill, M.S., et al., *Older drivers' insight into their hazard perception ability.* Accident Analysis and Prevention, 2011. **43**: p. 2121-2127.
3. Wood, J.A., P.F. Lacherez, and K.A. Anstey, *Not all older adultshave insight into their driving abilities: Evidence from an on-road assessment and implications for policy.* Journals of Gerontology: Medical Sciences, 2012.
4. Wood, J.A., et al., *A multidomain approach for predicting older driver safety under in-traffic road conditions.* Journal of the American Geriatrics Society, 2008. **56**: p. 986-993.
5. Hutchinson, C.V., et al., *Psychophysical correlates of global motion processing in the aging visual system: A critical review.* Neuroscience and Biobehavioral Review, 2012. **36**: p. 1233-1272.
6. Bullimore, M.A., J.A. Wood, and K. Swenson, *Motion perception in Glaucoma.* Investigative Ophthalmology & Visual Science, 1993. **34**(13): p. 3526-3533.
7. Lord, S., R.D. Clark, and I.W. Webster, *Physiological factors associated with falls in an elderly population.* Journal of the American Geriatrics Society, 1991. **29**: p. 1194-1200.

Appendix – Guide to Installation

Dot Motion Test

Installing:

First install the latest standalone version of Psychopy for your computer.

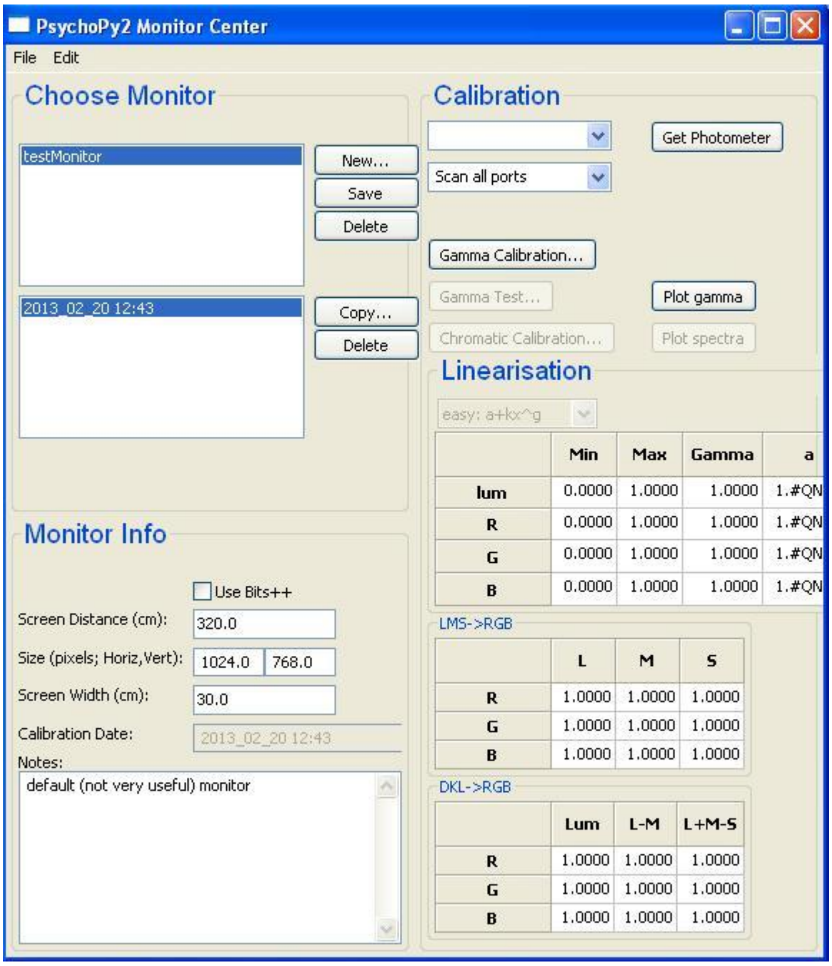
http://www.psychopy.org/installation.html

Once this is installed, unzip the folder provided wherever you want on your computer. The program is called 'Dotmotion.py'. On a windows machine it may not work when double clicked the first time, because python does not tend to be associated with the .py extension automatically. So double click it and then:

On a windows computer choose 'Select program from a list' then click **Browse** and then navigate to the psychopy directory which will usually be in C:/Program Files/Psychopy2 or C:/Program Files (x86)/Psychopy2. Select 'python.exe'. The program should run.

Run this on a screen with 1024*768 resolution or as close as possible. The motion thresholds will not be completely comparable with previous research unless the resolution is close to this. Usually, you get to the screen settings on Windows by right-clicking on the empty desktop and choosing properties, and under the settings tab drag the slider to the preferred resolution (however your graphics card may have another driver and so this may not work for all systems).

Also, ensure the Monitor configurations within PsychoPy are set up accordingly. To do this, open PsychoPy, go to Tools > Monitor Centre, and make sure Screen Distance and Size are 320cm and 1024 by 768 respectively and the screen width is correct for your monitor.



Postural Sway Test

Instructions:

Download PPA Sway Path App onto iPad (see link https://itunes.apple.com/au/app/ppa-sway-path/id567919398?mt=8&ign-mpt=uo%3D2).

Colour Choice Reaction Time Test

Installation and Set-up

Copy the folder RTCar located on the Flash Drive that accompanies the Multi-D Test Battery onto your computer. Plug the Response box USB into USB port on your computer.

To install the drivers for the Response box:

1. Go to Start -> Control Panel -> System -> Device Manager
2. Expand the port section and right click the newly identified name of the port, possible name is Eleven
3. Right click on the new device. Select Properties -> Driver -> Update driver
4. Choose browse my computer for driver software
5. Choose let me pick a list of device driver on my computer
6. Click on 'Have disk' button then 'browse'
7. Open RTCar folder. Click on the 'FreetronicsUSB_v1_0.inf'
8. Open -> OK -> next

   Alternatively, follow this link:

   http://www.freetronics.com/pages/installing-the-usb-driver-file-for-windows#.UNLFMXe60cY

9. Proceed with the driver installation even if the driver is not digitally signed.

When this happens on **Windows 8** and the go next button is greyed out, please follow:

10. Press Windows Key + R
11. Enter shutdown.exe /r /o /f /t 00
12. Click the 'OK' button
13. System will restart to a 'choose an option' screen
14. Select 'Troubleshoot' from 'Choose an option' screen
15. Select 'Advanced options' from 'Troubleshoot' screen
16. Select 'Windows Startup Setting' from 'Advanced options' screen
17. Click 'Restart' button
18. System will restart to 'Advanced Boot Options' screen
19. Select 'Disable Driver Signature Enforcement'
20. Once the system starts, install the driver as described

Repairing pushbutton device script

1. Unzip the 'arduino-1.0.2-windows.zip' under 'RTCar\Buttonwithrequestzerosflush2' directory
2. Double click on the 'arduino.exe' in the unzipped folder
3. File -> Open
4. Open 'Buttonwithrequestzerosflush2.ino' under 'RTCar\Buttonwithrequestzerosflush2' directory
5. File -> Upload

On Computer with Matlab installed

1. Install the Psychtoolbox

    For 32 bits Windows, install 'Slik-Subversion-1.7.7-win32.msi' under the 'RTCar\Psychtoolbox' directory

    For 64 bits Windows, install 'Slik-Subversion-1.7.7-x64.msi' under the 'RTCar\Psychtoolbox' directory

2. Open Matlab with administrative privilege
3. Point the Matlab current directory to 'RTCar\Psychtoolbox'
4. In command window, type:

    mypath=cd; (Enter to proceed)

5. DownloadPsychtoolbox(mypath) (Enter to proceed)

    Alternatively, follow this link

    http://psychtoolbox.org/wikka.php?wakka=PsychtoolboxDownload#installation

Running the Matlab script

1. Point the Matlab current directory to 'RTCar\Test Battery'

For user without the Instrument Control Toolbox:

1. Rename 'myguiport.m' to 'myguiport_old.m'
2. Rename 'myguiport_withoutICT.m' to 'myguiport.m'
3. In command window, type ctb (enter to proceed)

Standalone application

For 32 bits Windows:

1. Located within the RTCar folder is a folder called "32bitsWins," open this folder
2. Install 'MCRInstaller.exe' located in this folder
3. Run the application by double clicking on the 'ctb.exe' under the 'RTCar\32bitsWins' directory (Note: ctb.exe appears once MCRInstaller.exe installation is complete)
4. If error about the mex module comes out:
   Install 'vcsetup.exe' (Visual Studio) under the 'RTCar\C library' directory

For 64 bits Windows:

1. Located within the RTCar folder is a folder called "64bitsWins," open this folder
2. Install 'MCRInstaller.exe' located in this folder
3. Run the application by double clicking on the 'ctb.exe' under the 'RTCar\64bitsWins' directory
4. If error about the mex module comes out:
   Install 'vcsetup.exe' (Visual Studio) under the 'RTCar\C library' directory
   Install 'gstreamer-sdk-x86_64-2012.11.msi' under the 'RTCar\C library\64bits C library' directory

Troubleshooting

If you find that the Colour Choice RT test is running too slowly or not working at all despite correct installation, try the following:

- Use a different USB port and restart the program
- Change USB cable
- Update your computer processor
- Update your graphics card driver