Self-Awareness of Driving Performance in Older Adults

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DEDICATIONS

To my beloved grandparents, father, mother, and my brother.

How lucky I am to be born, raised, supported, and loved in this family!

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
AOTA	American Occupational Therapy Association
df	Degrees of Freedom
Candrive	Canadian Driving Research Initiative for Vehicular Safety in the Elderly
CI	Confidence Interval
CRIR	Centre for Interdisciplinary Research in Rehabilitation of Greater Montreal
DEC Model	Driving as Everyday Competence Model
DRC	Driving Rehabilitation Centre
eDOS	Electronic Driving Observation Schedule
HML	Hamilton
GDS	Geriatric Depression Scale
GPS	Global Positioning System
IADL	Instrumental Activities of Daily Living
ICC	Intraclass correlation
IQR	Interquartile Range
mCIRS_N	Modified Cumulative Illness Rating Scale: number of comorbid conditions
mCIRS_Sev	Modified Cumulative Illness Rating Scale: severity of comorbid conditions
MoCA	Montreal Cognitive Assessment
MTL	Montreal
MVPT-3	Motor Free Visual Perception Test
NDO	Naturalistic Driving Observation
OECD	Organisation for Economic Co-operation and Development
OR	Odds Ratio
OTT	Ottawa
PDA	Perceived Driving Ability Questionnaire
PEO	Person-Environment-Occupation Model
SD	Standard deviation
SODE	Standard On-Road Driving Evaluation
TMT	Trail Making Test

TUG Timed Up and Go Test

WHO World Health Organization

ABSTRACT

The number of older drivers in developed countries is rapidly growing; many have a strong desire to use their car for outdoor mobility. However, their driving ability may be diminished due to age-related functional decline and medical conditions, leading to a higher crash risk. Having accurate self-awareness of their driving ability may be one important factor to enable older drivers to adopt appropriate self-regulatory behaviors and maintain safe driving performance in their everyday living for as long as possible.

The accuracy of self-awareness is defined by the correspondence between one's perceived and actual ability. Regarding the literature on older drivers' self-awareness of their driving ability, some methodological issues and knowledge gaps exist. In past studies, questions used to assess perceived driving ability were too general and did not guide respondents to reflect on their driving ability in specific maneuvers and conditions. Some used questions requiring older drivers to compare their driving ability to others, which likely resulted in biased positive responses. Older adults' driving ability was usually assessed using the standard on-road driving evaluation (SODE); the structured evaluation context reduces its ecological validity in representing their everyday driving performance. Instead, the naturalistic driving observation (NDO) may be a better approach to record older drivers' everyday driving behavior in an environment familiar to them. In addition, studies examining the characteristics of older drivers who under, accurately, and overestimated their driving ability were scarce, and the findings were not consistent; also, there were no longitudinal studies found in the literature.

The overall objective of this thesis was to contribute evidence towards older drivers' self-awareness of their driving ability in a naturalistic driving environment. To compare and contrast how the SODE and the NDO approaches influence older adults' driving performance, a reflective literature review was completed and published using the Person-Environment-Occupation Model. This study highlighted that, during the SODE, older drivers' performance may be negatively impacted by test anxiety and the unfamiliar environment, but changes in their driving capacity over time can be measured in this structured context. On the contrary, using the NDO approach, older drivers can adjust their driving behavior and environment based on their self-awareness of driving ability and self-regulatory modifications; by reducing the demands of their driving

environment, their driving performance could be stable over time despite changes in their driving capacity (Manuscript #1).

Based on the previous study, a validated NDO approach, the electronic Driving Observation Schedule (eDOS), was adopted to evaluate older drivers' performance in their everyday driving environment. Some improvements to its scoring system were required. One issue was that the driving environment during each eDOS differs from each other, so the comparison of driving performance between clients or across observation sessions would be problematic. Also, the original formula of the eDOS total score was calculated by the proportion of errors made during the drive. While some driving errors are riskier than others, depending on the error type, the driving maneuver, and the environment complexity in which they occur, a better weighted score was needed. Thirteen experts in driving rehabilitation were consulted to address these issues using a two-round on-line survey. A weighted maneuver/environmental complexity score was created to represent the complexity of the driving route. A weighted eDOS total score was generated to better reflect older adult's driving performance by taking into consideration of the risk levels of each driving error (Chapter 4).

The next study examined the accuracy of older drivers' self-awareness of driving ability and its associated demographic and clinical factors. Perceived driving ability was assessed using the Perceived Driving Ability [PDA] questionnaire, a valid and reliable tool and the weighted eDOS score was used to represent everyday driving performance. By comparing the two scores, 108 older drivers were classified into 3 groups based on the accuracy of estimation of their driving ability: under-estimation (19%); accurate (29%); over-estimation (53%). An ordinal regression model showed that older drivers who over-estimated their driving ability had better visuo-motor processing speed and fewer comorbid conditions (Manuscript #2). A longitudinal study was administered to further examine older drivers' self-awareness of their changes in driving ability over time (n=60). Results showed that most participants had worse driving performance at the second session, regardless of their perceived changes in driving ability. Approximately one-third of the older drivers did not detect their declining driving ability over one year (Manuscript #3).

The findings from this thesis indicate that many older drivers over-estimated their driving ability and did not perceive their declining driving performance over one year. Future studies are needed to examine the relationship between older drivers' accuracy of self-awareness and crash risk, as well as to create intervention programs for enhancing their accuracy of self-awareness of driving ability.

ABRÉGÉ

Avec le vieillissement de la population, le nombre de personnes âgées qui conduisent dans les pays développés s'accroit sans cesse. Avec une mobilité physique réduite et la non proximité des services, surtout en banlieue, le besoin d'utiliser un véhicule motorisé pour se déplacer devient de plus en plus important. Par contre des changements reliés au vieillissement normal et à des problèmes de santé peuvent altérés les capacités de conduite sécuritaire, ce qui peut entraîner un risque plus élevé d'accidents. Une perception adéquate de ses propres aptitudes de conduite est un des facteurs importants permettant aux conducteurs d'adopter des comportements de conduite plus sécuritaires et des mesures compensatoires afin de pouvoir conduire le plus longtemps possible.

L'exactitude de l'autoperception de ses capacités de conduite est définie par la correspondance entre la perception de ses capacités et les habiletés réelles. Il existe toutefois des problèmes méthodologiques et un manque de connaissance en ce qui a trait à l'évaluation de l'autoperception des aptitudes de conduite des personnes âgées dans la littérature scientifique. Les questionnaires utilisés dans les études précédentes pour évaluer les aptitudes de conduite étaient trop généraux et ne permettaient pas d'évaluer les conducteurs sur des manœuvres et situations de conduite particulières. De plus, certaines études utilisaient des questions demandant au conducteur âgé de se comparer à d'autres conducteurs, ce qui peut entrainer des réponses positives biaisées. L'évaluation routière habituellement utilisée dans ces études était une évaluation standardisée effectuée dans un programme d'évaluation de la conduite automobile; le contexte standardisé dans lequel sont effectuées ces évaluations peut ne pas refléter les conditions et l'environnement de conduite quotidien de la personne évaluée. Une meilleure approche serait d'utiliser une observation en situation réelle de conduite afin d'évaluer les capacités de conduite des personnes dans un milieu familier. Finalement, les études qui ont examiné les caractéristiques des conducteurs qui sous-estiment, surestiment et estiment correctement leurs aptitudes de conduite sont rares et les conclusions ne sont pas toujours cohérentes. De plus, aucune étude longitudinale sur ce sujet n'a été recensée dans la littérature scientifique.

L'objectif principal de cette thèse est de contribuer au développement des connaissances sur l'autoperception des aptitudes de conduite des personnes âgées dans leur milieu de conduite réel au quotidien.

En premier lieu, nous avons comparé deux méthodologies d'évaluation de la conduite sur route, l'évaluation sur route standardisée (ERS) et l'observation de conduite en milieu naturel (OCMN), afin de mieux comprendre comment ces dernières peuvent influencer la performance des conducteurs. Le modèle personne-environnement-occupation a été utilisé afin de comparer les deux approches. Cette revue publiée nous a permis de constater que, durant le ERS, la performance des conducteurs âgés pouvait être influencée par l'anxiété reliée à la situation d'évaluation et la non familiarité avec le véhicule et les circuits routiers utilisés. Par contre, cette approche permet de mesurer adéquatement les changements des compétences de conduite à travers le temps grâce au contexte structuré de l'approche. De son côté, le OCMN permet d'observer si un conducteur peut utiliser des stratégies compensatoires de conduite dans son milieu quotidien grâce à une bonne perception de ses compétences et limites. En modifiant l'environnement de conduite afin d'en diminuer les exigences, un conducteur pourrait continuer à conduire de façon sécuritaire plus longtemps même s'il y a des changements dans ses aptitudes de conduite. (Manuscrit #1)

The electronic Driving Observation Schedule (eDOS), une approche d'OCMN validée, a été adopté pour évaluer la performance des conducteurs dans leur environnement de conduite quotidien. Afin de mieux refléter la capacité de conduire des personnes évaluées, il était nécessaire d'effectuer des améliorations au système de cotation. Premièrement, comme les manœuvres et les lieux d'évaluation diffèrent d'un conducteur à l'autre, nous avons dû établir un système de cotation tenant compte de la complexité des manouvres effectuées et de l'environnement de conduite pour chaque évaluation afin de pouvoir les comparer entre elles. Deuxièmement, la formule originale pour calculer le score final du eDOS ne tenait compte que de la proportion d'erreurs durant l'évaluation. Certaines erreurs ou infractions sont beaucoup plus graves que d'autres dépendamment du type de manouvre effectuée et de la complexité de l'environnement ou elles surviennent et devraient donc avoir un poids plus grand sur le score final. Une pondération qui tient compte de la gravité des infractions nous donne aussi une meilleure appréciation des risques réels pour les conducteurs. Nous avons donc mené un sondage en ligne en deux phases avec treize experts en réadaptation de la conduite afin d'établir deux formules pour permettre l'évaluation de la complexité des manœuvres/environnements de conduite et obtenir un score total pondéré (Chapitre 4).

L'étude suivante avait pour but d'étudier l'exactitude de l'autoperception des capacités de conduite chez des conducteurs âgés et les facteurs démographiques et cliniques qui y sont associés. La perception des aptitudes de conduite a été évaluée à l'aide du questionnaire « Perceived Driving Ability (PDA) », un outil valide et fiable, et le score total pondéré du eDOS a été utilisé afin de mesurer la performance de conduite au quotidien. En comparant les résultats obtenus aux deux mesures, nous avons pu classer les 108 participants dans trois catégories selon l'exactitude de l'estimation de leur aptitude de conduite : sous-estimation (19%), estimation exacte (29%), surestimation (53%). Un modèle de régression ordinale a démontré que les conducteurs qui surestiment leurs compétences de conduite ont une meilleure coordination visuo-motrice et moins de comorbidités (Manuscrit #2). Nous avons aussi effectué une étude longitudinale pour évaluer les changements au niveau de l'autoperception des capacités de conduite sur un an auprès de 60 conducteurs âgés. Les résultats ont démontré qu'environ un tiers des conducteurs âgés n'avaient pas perçu le déclin de leurs capacités de conduite. Les participants qui avaient de moins bonnes performances de conduite à la deuxième session, indépendamment de leurs changements de capacité de conduite (Manuscrit #3).

Les résultats de cette thèse démontrent que plusieurs conducteurs âgés ont surestimé leur capacité de conduite au quotidien et n'ont pas perçu un déclin de leurs aptitudes de conduite sur une année. Des études supplémentaires devront être effectuées pour examiner la relation entre l'exactitude de l'autoperception des aptitudes de conduite et le risque d'accidents chez les conducteurs âgés. Des programmes d'interventions devront aussi être créés pour améliorer l'autoperception de la capacité de conduite des conducteurs âgés.

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STATEMENT OF ORIGINALITY

This PhD dissertation is an original scientific work in a manuscript-based format. At the time of thesis submission, the first manuscript (Chapter 3) has been published; the second manuscript (Chapter 5) has been submitted for publication; and the third manuscript (Chapter 6) is in preparation to be submitted to a peer-reviewed journal.

Chapter three (manuscript #1) is an original piece of work, which systematically compared two on-road driving evaluation approaches using a prominent model in rehabilitation science. This analysis has never been done before and the findings can inform clinicians about how to choose an appropriate approach for assessing older adults' driving ability and performance.

Chapter four describes a study using an on-line survey to consult experts in driving rehabilitation for the purpose of creating a score to represent the complexity of driving maneuvers and environments during naturalistic driving observations, as well as a weighted score to indicate older adults' everyday driving performance by accounting for the type of driving errors and its corresponding environment. The driving maneuver/environment complexity score is a new concept that has never been established before and is important to illustrate the difficulty level of drivers' everyday driving maneuvers and environments. The weighted score is a major improvement over the original method used to quantify older adults' driving performance, as differences in the risk level of each driving error were considered.

Chapter five (manuscript #2) is a unique scholarship using older drivers' naturalistic driving performance to assess the accuracy of their perceived driving ability. Their self-awareness was defined by the correspondence between their perceived and actual driving ability and participants were categorized into under-, accurate, and over-estimated groups. Compared to previous studies that have only used generic questions to address older drivers' perceived driving ability and standard on-road driving evaluations to assess their actual driving ability, this study is the first to measure older drivers' self-awareness by adopting a more detailed, driving-centred questionnaire to assess perceived driving ability and a naturalistic driving observation approach to evaluate their everyday driving performance. Findings from this study provide a new aspect of older drivers' self-awareness in an ecological environment. Moreover, this study found that visuo-motor processing speed and the number of comorbid conditions are related to older drivers' accuracy of self-awareness. These factors associated with self-awareness have never been reported before.

Chapter six (manuscript #3) expanded the research of the second manuscript and investigated older drivers' self-awareness of changes in driving ability over a one-year period and its associated demographic and clinical factors. This longitudinal study is a new contribution to the scientific evidence about the accuracy of how older drivers detect and monitor their driving ability over time.

CONTRIBUTION OF AUTHORS

The doctoral candidate and author of this thesis, Yu-Ting Chen, conducted the literature review, data collection, and data analysis for all the studies under close supervision of Dr. Isabelle Gélinas (supervisor), and Dr. Barbara Mazer (co-supervisor). All the manuscripts were composed by Yu-Ting Chen with Dr. Gélinas and Dr. Mazer' critical review and editing.

Chapter three (manuscript #1): Yu-Ting Chen did the literature review and wrote the draft of this manuscript. The co-authors, Dr. Isabelle and Dr. Mazer, provided direction and feedback, also helped with editing.

Chapter four: Dr. Gélinas, Dr. Mazer, and Yu-Ting Chen worked together as the primary investigators for this study. Dr. Gélinas and Dr. Mazer assisted in participant recruitment and study ethical review; Yu-Ting Chen created and administered the on-line survey, analyzed the data, and composed the content of this chapter. The study design and interpretation of the results were completed by the primary investigators collaboratively.

Other co-authors of this study, Dr. Brenda Vrkljan, Dr. Sjaan Koppel, Dr. Judith Charlton, and Dr. Shawn C. Marshall, provided their comments and feedback on the interpretations of the study results, and also reviewed the manuscript.

Chapter five and six (manuscript #2 and #3): Dr. Gélinas, Dr. Mazer, and Yu-Ting Chen designed the studies. Yu-Ting collected and analyzed the data and prepared the manuscripts. Other co-authors provided their editorial comments on the manuscripts and approved their content.

THESIS ORGANIZATION AND OVERVIEW

The organization of this manuscript-based thesis adheres to the guidelines for thesis preparation published by McGill Graduate and Postdoctoral Studies. This section states the required thesis components and their corresponding chapters.

Chapter 1 is a comprehensive literature review related to the topic of older drivers' self-awareness of driving ability in their naturalistic driving environment. This review follows the funnel technique of introduction writing, which starts from broader issues and narrows down to specific research questions. Eight sections are included in this review: i) older drivers in developed countries; ii) models of driving behavior; iii) self-regulatory behaviors among older drivers; iv) self-awareness; v) self-awareness of driving ability among older drivers; vi) measurement of self-awareness of driving ability; vii) factors associated with self-awareness of driving ability, and viii) summary.

Chapter 2 states the study rationale and objectives.

Chapter 3 presents manuscript #1 entitled "Determining older adults' fitness-to-drive: Comparing the standard on-road driving evaluation and the naturalistic driving observation". This is a reflective literature review that compared and contrasted the standard on-road driving evaluation and the naturalistic driving observation approaches, using the Person-Environment-Occupation (PEO) model. This manuscript has been published in the journal Physical & Occupational Therapy in Geriatrics.

Chapter 4 describes the study: "Development of a weighted scoring system for the eDOS". This is not a manuscript, but this chapter presents a study that was designed to improve the scoring system used for one of the main outcome measures, the electronic Driving Observation Schedule (eDOS). The new scoring system was adopted to represent older drivers' everyday driving performance in the following manuscripts.

Chapter 5 is composed of a preface and the manuscript #2. The preface articulates the connection between chapter four and manuscript #2. The manuscript included in this chapter, "Personal and clinical factors associated with older drivers' self-awareness of driving performance" is a cross-sectional study aimed to determine the accuracy of older drivers' self-awareness of driving ability in their everyday driving environment and its relationship with demographic and clinical factors. This manuscript has been submitted to the Canadian Journal on Aging for review.

Chapter 6 consists of a preface and manuscript #3. The preface explains the connection between manuscript #2 and manuscript #3. The manuscript #3 entitled "Longitudinal changes in older drivers' self-awareness of driving ability" is a longitudinal study describing older drivers' self-awareness of changes in driving ability over one year and its association with demographic characteristics and changes in clinical functioning.

Chapter 7 presents the discussion of the overall findings from studies included in Chapters 3 to 6. This chapter summarizes the main findings from these studies, presents the interpretation of the results and study limitations, as well as suggests future research directions and clinical implications. A conclusion is included at the end of this chapter.

Corresponding figures, tables, and references are presented at the end of each chapter; the references for Chapter 1 (Literature review) and Chapter 7 (Discussion) are presented together after Chapter 7. Appendices that can assist readers to further comprehend the thesis contents are included at the end of the thesis.

CHAPTER 1: LITERATURE REVIEW

1.1 OLDER DRIVERS IN DEVELOPED COUNTRIES

1.1.1 Demographic information and importance of driving in older age

The population is aging in most developed countries. In Canada, the number of persons aged 65 years and over is expected to double in the next two decades (from 5.4 million to 10.5 million) (Statistics Canada, 2011). This age group accounted for 15.3% of Canadians in 2013 and is projected to increase to 23% - 25% of the population by 2036 (Statistics Canada, 2011). The rapid growth rate of the older population is associated with longer life expectancy and aging baby-boomers (Bonder, 2009).

Maintaining independent mobility in older drivers is one of the priorities for governments in developed countries (Organisation for Economic Co-operation and Development [OECD], 2001), and the concern of safe driving is of crucial importance (Eby & Molnar, 2009). Driving a private vehicle is the most common and preferred mode of transportation among older adults in North America (Burkhardt & McGavock, 1999; Sleightholm, Billette, Normandin, & Hofmann, 2010; Statistics Canada, 2010). Older adults report that driving a private vehicle provides them freedom, convenience, and autonomy, and is preferred over using public transportation (Dickerson et al., 2007; Newbold, Scott, Spinney, Kanaroglou, & Páez, 2005; Turcotte, 2009). In Canada, 75% of this age group (i.e., 3.25 million) held a valid driver's license in 2009, and 90% drive at least once a week (Statistics Canada, 2010).

Moreover, the number of older drivers, their annual mileage and their average annual number of trips have rapidly increased since the 1970s, and the trend is accelerating (Eby & Molnar, 2009; Hu & Reuscher, 2004) (See Figure 1.1). By 2030, it is estimated that the number of drivers over the age of 84 years will be at least 3.5 times greater than the number in 1996, as a result of the aging population and the increasing number of women drivers (Burkhardt & McGavock, 1999). Also, since the upcoming cohort of older drivers has a more active lifestyle than previous generations, they are projected to drive longer and farther distances compared to earlier cohorts of older adults for fulfilling their greater outdoor needs in activities of daily living, work, social and recreation activities (Newbold, Scott, Spinney, Kanaroglou, & Páez, 2005; Rudman, Friedland, Chipman, & Sciotino, 2006; OECD, 2001; Santos, McGuckin, Nakamoto, Gray, & Liss, 2011).

Literature related to driving cessation also highlights the importance of driving among older drivers. Many drivers voluntarily or involuntarily quit driving at a later age. However, driving cessation is associated with a plethora of negative psychosocial consequences, including decreased out-of-door activities (Marottoli et al., 2000), feelings of isolation and loneliness (Azad, Byszewski, Amos, & Molnar, 2002), depressed mood (Ragland, Satariano, & MacLeod, 2005), and increased family burden (Taylor & Tripodes, 2001). Assisting older drivers to continue to drive safely could avoid or postpone these negative conditions, and better prepare them for changes in lifestyle after driving retirement.

1.1.2 Safety concerns related to driving

Crashes, injuries and death among older drivers. Older drivers are perceived by the public as having high crash rates. Early research examining older drivers' crash involvements also supported this point of view and made pessimistic predictions about future road safety (Bédard, Stones, Guyatt, & Hirdes, 2001; Burkhardt & McGavock, 1999; Lyman, Ferguson, Braver, & Williams, 2002). In fact, older drivers over the age of 65 years have the second greatest number of crashes per vehicle-kilometer travelled, after teenage drivers (Cicchion & McCartt, 2014). Their likelihood of having a crash increases with age, and triples for drivers age over 80 years compared to drivers 65 to 69 years (Li, Braver, & Chen, 2003; Meulerners, Harding, Lee, & Legge, 2006).

More older drivers on the road do not equal to more car crashes. The involvement rates of older drivers in fatal crashes, nonfatal injury crashes, and property-damage-only crashes, after adjusting for vehicle-kilometer travelled, are decreasing over time, and the decline is faster than that of middle-aged drivers (Cheung & McCartt, 2011; Cicchion & McCartt, 2014; Hakamies-Blomqvist, Wiklund, & Henriksson, 2005; Thompson, Baldock, & Dutschke, 2018). These findings were consistent in Australia, the United States, and Great Britain. Cicchino (2015) suggested that this trend may be related to the decrease of low-mileage older drivers (i.e. drivers driving less than 3,000 kilometres per year), who have higher crash rate per distance driven compared to those who maintain a stable driving mileage per year, and better health conditions among the more recent cohort of older drivers. In other words, a greater number of active older drivers on the road is not associated with a higher likelihood of crash involvement.

Moreover, involvement in crashes may be riskier to these drivers than to other road users. Older drivers are more likely to be killed or injured due to their more fragile body structure, which is less able to tolerate the impact and recover from the impact of a car crash. Several studies examined the relative relationship between driver deaths per crash involvement (as an indicator of fragility) and crash involvement per vehicle-mileage (as an indicator of crash over-involvement) across different age groups (Li, Braver, & Chen, 2003; Meuleners, Harding, Lee, & Legge, 2006). They concluded that for older drivers, fragility overrides crash over-involvement as a main contributor of fatal crashes, except for male drivers aged over 80 years. Instead of causing or being involved in more crashes, older drivers may have more crash records than middle-aged drivers because the consequences of a crash tends to be more severe.

Impact of functional impairments and medical conditions on driving performance. Driving a vehicle safely and efficiently in traffic is a complex task. To reach destinations, drivers need sufficient skills to plan a trip, operate a vehicle, interact with other road users, and follow traffic signs and rules. These driving skills require the integration of visuo-perceptual, psychomotor, cognitive, and executive functioning (Anstey, Wood, Lord, & Walker, 2005), and their driving pattern could be impacted by their comorbid conditions, mood status (O'connor, Edwards, Small, & Andel, 2012; Papa et al., 2014), as well as driving experience and history of crashes (O'Connor et al., 2010; Xu, Li, & Jiang, 2014).

Although aging itself is not detrimental to these critical driving skills and the related driving performance, age-related functional impairments and medical conditions may be (Ball et al., 2006; Dobbs & Carr, 2005; McGwin Jr., Sims, Pulley, & Roseman, 2000). Natural functional changes with aging, such as slower visual processing speed, poorer contrast sensitivity, weaker lower limb muscle strength, declines in cognitive function, and poorer balance, may affect older adults' fitness to drive (Lacherez, Wood, Anstey, & Lord, 2014; Mathias & Lucas, 2009; Sandlin, McGwin Jr., & Owsley, 2014; Wood, Chaparro, Lacherez, & Hickson, 2012). Some degenerative and chronic diseases, such as stroke, Alzheimer's disease, Parkinson's disease, and macular degeneration, as well as medications for symptom treatment, may also have an impact on older adults' driving capacity (Anderson et al., 2012; Carr & Ott, 2010; McGwin Jr. et al., 2000; McGwin Jr. et al., 2013).

1.1.3 Maintaining older drivers to drive safer and longer

The literature reviewed in the last sections indicated that driving has a profound influence on older drivers' activities of daily living and quality of life, but their declining body functioning may impact their safety on the road. For front line health care professionals who are screening and evaluating older adults' fitness-to-drive, balancing their clients' needs for outdoor mobility and the public's safety is crucial. The prevailing approach is to keep older adults driving safer and longer while preparing them for driving retirement as early as possible (e.g. explore and familiarize the other mode of transportations) (Langford & Koppel, 2006; Oxley & Whelan, 2008).

One of the key factors that may influence older drivers' everyday driving safety is the accuracy of their self-awareness of their driving ability. Models in traffic psychology and driving rehabilitation have proposed that accurate self-awareness of driving ability is a trigger for necessary behavior change that will influence one's driving performance (Kowalski, Jeznach, & Tuokko, 2014; Lindstrom-Forneri, Tuokko, Garrett, & Molnar, 2010). However, scientific studies addressing this factor among older drivers is scarce. Prior to examining the literature associated with older drivers' self-awareness of driving ability and identifying knowledge gaps, two models that illustrate drivers' behavior and factors modify their driving performance will be introduced. These two models, the Michon's hierarchical model (Michon, 1985) and the Driving as an Everyday Competence (DEC) model (Lindstrom-Forneri, Tuokko, Garrett, & Molnar, 2010), were selected because of their wide use in the field of driving rehabilitation.

1.2 MODELS OF DRIVING BEHAVIOR

1.2.1 Michon's Hierarchical Model

Michon's hierarchical model (1985) is one of the most commonly applied models in driving rehabilitation. In this model, a driver is considered an active, conscious decision maker on the road, and also a passive, automatic responder to traffic (i.e. consistent with motivational models and information-processing models; for a complete review of these driving models, see Ranney, 1994). Based on these concepts, a three-level hierarchy of cognitive control on driving behavior was proposed, which involves strategic, tactical (or maneuvering), and operational levels of controls.

The *strategic level* involves general trip planning ahead of the drive, including selecting routes, driving conditions and destinations, as well as preparing navigation aids (e.g. maps and GPS devices) and assistants (e.g. a co-pilot). Drivers consciously make decisions at the strategic level for meaningful, functional purposes, such as minimizing travel duration, decreasing driving risks or costs. Drivers' cognitive control at the *tactical level* occurs in a few seconds before and during the encounter with other vehicles and road users for making safe maneuvers in certain contexts. For example, merging into the main traffic flow from a residential street, changing lanes on a highway, or finding a safe gap to make a left turn at an intersection. These decisions are mainly driven by the driving environment, but also requires drivers' accurate estimation and judgement of traffic conditions. The *operational level* is related to immediate use of vehicle controls, such as steering, braking, and using vehicle control apparatus (e.g. windshield wipers). For experienced drivers, manipulations at the operational level are mostly automatic actions free of heavy cognitive workloads (Michon, 1985; Ranney, 1994).

The Michon's hierarchical model provides a common language to discuss drivers' decision making and behavior at different cognitive levels. This terminology will be used in the following sections of this dissertation.

1.2.2 Driving as an Everyday Competence (DEC) Model

The DEC model (Figure 1.2) was developed and revised by a group of interdisciplinary health care researchers from the Canadian Driving Research Initiative for Vehicular Safety in the Elderly (CanDRIVE) team. Inspired by the concept of everyday competence (Willis, 1991), Michon's Hierarchical Model (Michon, 1985), Anstey's Multi-Factorial Driving Model (Anstey, Wood, Lord, & Walker, 2005), Fuller's Task-Capability Interface Model (Fuller, 2005), and experts' opinion (Dickerson et al., 2007), the DEC model is a comprehensive model that describes the influence of personal and environmental factors, as well as their interactions, on driving competence and driving performance (Lindstrom-Forneri, Tuokko, Garrett, & Molnar, 2010).

The DEC model discriminates one's driving "competence" from driving "performance". A person's driving competence is defined as their "capability" to drive, or what they "can do" under given conditions. While one's driving competence always fluctuates with the driver's functional condition (i.e. personal factors) and the driving context (i.e. environmental factors), this variable is considered as an abstract concept that is not observable. Instead, what we can observe is a drivers' actual driving "performance". Driving performance represents what drivers "actually do" in their everyday driving, including their strategic trip planning and driving maneuvers at tactical and operational levels.

Regardless of one's driving competence, some "moderators" may alter a driver's performance in their everyday driving. These moderators are closely associated with the drivers' decision making and behaviors at strategic and tactical levels. Four important moderators that have been identified to affect a driver's driving behavior at the strategic level are beliefs, awareness, self-monitoring, and self-efficacy. These factors are self-perceived, psychological attributes related to how a driver appraises his or her own body functioning, how the status and changes in body functioning could affect their driving ability, how much risk they would take and how capable they are to drive in challenging conditions in which they feel "uncomfortable". These perceptions modify a driver's decisions regarding their everyday drives and impact their driving performance. For example, a male older driver who is aware of his poorer vision due to macular degeneration may postpone an appointment to avoid driving in heavy rain with poor visibility; a female older driver who believes her mobility and reaction time are declining may avoid driving in complex traffic conditions, such as driving during rush hour or on highways. These moderators could have similar influences of driving behaviors at the tactical level, such as a driver's decision to leave a longer following distance on highways or to wait for a wider gap for a turn. However, their effects on the operational level would be minimal for experienced drivers, since most of the maneuvers at this level are automatic vehicle operations without discernable decision-making processes (Davis, Conlon, Ownsworth, & Morrissey, 2016).

The DEC model provides a comprehensive framework to explain a driver's everyday driving competence and performance. The concept of how moderators change one's driving performance is critical to enhance older adults' everyday driving safety. If an older driver can appropriately appraise and monitor changes in driving ability, he/she is more likely to voluntarily make proper trip planning and modifications, such as avoiding driving on highways or on rainy days. Less exposure in complex, high-risk driving conditions could enable the driver to decrease crash risk in their daily living. In reverse, biased self-awareness of driving ability, including over-estimation and under-estimation of driving abilities, may lead to high risk exposure in everyday driving (Ross et al., 2009) or premature driving cessation (Charlton et al., 2006; Siren & Haustein, 2016). The following section will review the literature related to the relationship between the moderators and older drivers' driving behavior and safety, especially older drivers' modifications of driving behaviors and patterns called "self-regulatory behaviors". By the end of the section, it will be clear why, among the moderators, self-awareness of driving ability is the focus of this dissertation as it represents a key factor influencing older drivers' everyday driving performance.

1.3 SELF-REGULATORY BEHAVIORS AMONG OLDER DRIVERS

1.3.1 Definition of self-regulatory behaviors

Driving self-regulatory behaviors refer to older drivers' modifications in their everyday driving pattern and behaviors to avoid or limit their exposure in complex or challenging driving conditions or to adopt conservative driving maneuvering behaviors (Ball et al., 1998; Dickerson et al., 2007; Molnar et al., 2014). These modifications involve changes in driving patterns at the strategic level, such as reducing driving frequency and driving radius from home, and avoiding driving at night, on highways, during rush hours, or on rainy days. It also includes changes in driving behavior at the tactical level, such as keeping longer following distance from the car in front. Approximately 35% to 45% of older drivers reported that they avoid driving at night in bad weather or during rush hours (Hakamies-Blomqvist & Wahlström, 1998; Molnar et al., 2013), while 40% of the drivers reported that they leave a larger distance from the car ahead (Molnar et al., 2013).

1.3.2 The relationship between older drivers' self-regulatory behaviors and driving safety

Adopting self-regulatory behaviors, such as reducing exposure to complex driving situations and implementing more voluntary safe driving maneuvers, is believed to reduce older drivers' crash risk as well as helping them to maintain their outdoor mobility (Bergen et al., 2017). Hakamies-Blomqvist (1994) found that older drivers have fewer crashes at nighttime and in bad weather compared with middle-aged drivers. They inferred that the lower crash rates observed in these conditions may be attributed to their self-regulatory behaviors. Charlton et al. (2006) found that older drivers with a crash history in the past two years tend to adopt more self-regulatory behaviors. They suggested that older drivers adopted these self-regulatory behaviors as an attempt to lower their future crash risk. De Raedt & Ponjaert-Kristoffersen (2000) reported that older drivers with worse driving capacity (the lowest quartile in on-road standard evaluations) adopted more strategic self-regulatory behaviors in their everyday driving. Also, the older drivers without a crash history in the past 12 months reported more strategic and tactical self-regulatory behaviors than those with at-fault crashes.

Despite these positive research findings on the impact of the use of self-regulatory behaviors on enhancing older drivers' safety, other studies did not find them as effective. One randomized controlled trial study compared the effectiveness of an educational program on future crash risk among at-risk older drives with visual impairments (Owsley, McGwin Jr, Phillips, McNeal, & Stalvey, 2004). This educational program aimed at enhancing older drivers' self-awareness of their visual problems and engaging them to discuss self-regulatory behaviors that would be feasible for them. Although older drivers in the intervention group adopted more strategic self-regulatory behaviors across two years, their crash rate did not significantly differ from the control group. Another study also found that at-risk older drivers with worse visuo-cognitive processing speed adopted a greater number of self-regulatory behaviors, but still had higher crash risk than healthy older drivers (Ross et al., 2009).

These contradictory findings might be due to differences in study participants. While self-regulatory behaviors among healthy older drivers are likely to help them maintain driving safety, they may not be sufficient for at-risk older drivers with impairments to counterbalance their declined driving abilities, thus, their crash risk remained high. For older drivers with functional impairments, providing other intervention programs (e.g. programs that target remediating or compensating for their impairments) on top of promoting self-regulatory behavior may be necessary. However, this issue is out of the scope of this dissertation since the following studies will focus on community-dwelling older drivers without severe functional impairments.

1.3.3 Factors associated with self-regulatory behaviors

Many studies have identified a wide range of factors associated with increased strategic self-regulatory behaviors, including demographic characteristics (i.e. older age, female gender) (Chalrton et al., 2006; D’ambrosio, Donorfio, Coughlin, Mohyde, & Meyer, 2008; Kostyniuk & Molnar, 2008; Molnar et al., 2014; Sargent-Cox, Windsor, Walker, & Anstey, 2011), psychosocial attributes (e.g. lower self-efficacy, worse perceived driving ability, poorer confidence in and comfort of driving) (Ackerman, Vance, Wadley, & Ball, 2010; Blanchard & Myers, 2010; Baldock et al., 2006; Charlton et al., 2006; Conlon, Rahaley, & Davis, 2017; Davis & Conlon, 2017; Meng & Siren, 2012; Molnar et al., 2014), changes in lifestyle in older age (e.g. retirement or decreased need to drive during rush hours) (Braitman & Williams, 2011; Molnar et al., 2013), family and social support (e.g. no family or friend could offer a ride if needed) (Charlton et al., 2006; Molnar et al., 2014); as well as tactical self-regulatory behaviors like worse contrast sensitivity (Molnar et al., 2014).

Among these factors, the psychosocial attributes were suggested to be the most influential on older drivers’ self-regulatory behaviors (Charlton et al., 2006; Meng & Siren, 2012; Molnar et al., 2014; Tuokko et al., 2013). For example, older drivers in advanced age and female drivers tend to adopt more self-regulatory behaviors due to lower confidence in driving in difficulty conditions (D’Ambrosio et al., 2008; Gwyther & Holland, 2012; Kostyniuk & Molnar, 2008). Drivers who perceived themselves as having better driving abilities drive in more challenging situations and more mileages per week (Blanchard & Myers, 2010; Jouk et al., 2014). Older drivers reported that their feelings of having difficulties with driving in certain conditions, such as seeing road signs at night, motivates them to avoid these driving conditions or modify their driving behavior (Musselwhite & Haddad, 2010; Rudman et al., 2006). The influence of these psychosocial attributes on self-regulatory behaviors corresponds to the effect of moderators on driving performance in the DEC model.

However, it is worth noting that one’s perception, confidence or beliefs in their driving ability, despite functioning as triggers of self-regulatory behaviors, may not be accurate. Studies have shown that older drivers’ self-regulatory behavior is not necessarily related to their actual visual, physical, and cognitive functioning (Ackerman et al., 2010; MacDonald, Myers, & Blanchard, 2008; Rapoport et al., 2013; Wong, Smith, & Sullivan, 2012) or driving performance in standard on-road driving evaluations (Baldock et al., 2006), and older adults' perception of driving ability is not associated with their prospective crash rates (Ross, Dodson, Edwards, Ackerman, & Ball, 2012). Inaccurate perception of one's driving ability can either facilitate or hinder an older adult's driving performance. Some drivers may lack awareness of their changes in driving ability and not adopt self-regulatory behaviors accordingly (Eby, Molnar, Shope, Vivoda, & Fordyce, 2003; Marottoli & Richardson, 1998; MacDonald et al., 2008); some drivers' self-regulatory behaviors may not be sufficient to counterbalance their deteriorating driving ability, causing them to keep driving in difficult conditions that exceed their driving capacity (Ross et al., 2009); and others may prematurely retire or avoid driving before they become unfit to drive (Charlton et al., 2006; Siren & Haustein, 2016). Although an older drivers' perception of driving ability is related to driving behavior modifications by avoiding or limiting their exposure in challenging conditions, the congruence between older drivers' perceived driving ability and their actual driving ability, ***the accuracy of their self-awareness of driving ability***, may have a more crucial impact on their everyday driving performance. The next section will focus on self-awareness of driving ability and will discuss definitions and the measurement of self-awareness of driving ability as well as review related literature.

1.4 SELF-AWARENESS

1.4.1 Definition of self-awareness

Various definitions of self-awareness have been published (Clare, Rowlands, Bruce, Surr, & Downs, 2008; Marrottoli & Richardson, 1998; Mosey, 1986; Prigatano & Schachter, 1991; Sunderaraman & Cosentino, 2017; Toglia & Kirk, 2000). The definition from Clair et al. (2008) is adopted for this dissertation because of its clarity, comprehensiveness, and clinical relevance. These authors defined self-awareness as "a reasonable or realistic perception of appraisal of one's situation, functioning, or performance, or of the resulting implications, expressed explicitly or implicitly" (Clare et al., 2008, p. 2367). Two important features of self-awareness could be highlighted based on this definition: the accuracy of one's perception (i.e. be reasonable and realistic) and appraisal of certain "objects" (e.g. one's situation, functioning, or performance).

Impaired self-awareness is a common clinical sign among clients with brain pathologies, including acquired brain injury, dementia, stroke, and schizophrenia (Chavoix & Insausti, 2017;

Prigatano, 2005; Sass & Parnas, 2003). Many clients with these conditions have no or only partial knowledge about their own impairments and have poor judgment on their impact on functional abilities and performance (Goverover, Chiaravalloti, Gaudino-Goering, Moore, & DeLuca, 2009; Okonkwo et al., 2009). Without reasonable or realistic self-awareness, they are likely to over-estimate their abilities and skills in various activities of daily living, leading to high risk exposure and low motivation towards necessary behavioral or environmental modifications (Gillen, 2009; Lindstrom, Eklund, Billhult, & Carlsson, 2013).

In addition, it is necessary to identify the "object" of self-awareness, such as clinical functioning or the performance of a task (Marková, Clare, Wang, Romero, & Kenny, 2005). Accurate self-perception of performance in one domain does not imply correctness in another domain (Toglia & Kirk, 2000). For example, Marková et al. (2014) reported that their levels of accuracy of self-awareness of memory functioning, performance in activities of daily living, and socio-emotional functioning are significantly different among older adults with early-stage dementia. Most participants over-estimated their memory functioning and performance in activities of daily living but under-estimated their socio-emotional functioning. Fleming & Strong (1999) also found that clients with brain injury have more accurate self-awareness in basic activities of daily living (e.g. dressing) compared to self-awareness in cognitively-demanding activities (e.g. driving or managing finances). Marková et al. (2005) argued that ambiguity of object is one reason for the contradictory results on how accurate clients with dementia are aware of their memory problems and suggested that the more precise the object is, the clearer the phenomenon of self-awareness could be understood.

1.4.2 Self-awareness of functional performance in healthy older adults

Most studies related to impaired self-awareness focused on clients with brain pathologies and proposed links with damages in several brain regions (e.g. prefrontal lobe, medial temporal lobe) (Prigatano & Schachter, 1991; Chavoix & Insausti, 2017). However, older adults with a normal aging process can also have impaired self-awareness of their functional performance. Fried et al. (1991) proposed the idea of "preclinical disability", referring to a stage when older adults have not yet experienced functional loss or disability, but demonstrate subtle signs of functional decline, such as shortness of breath or poorer night vision. The functional declines experienced by healthy older adults are mostly related to chronic disease (e.g. hypertension or diabetes) and are often progressive so that older adults at this stage may not be aware of the functional changes or impact on their activities of daily living. Some older adults at this stage may have partial self-awareness of their conditions, as they do not report difficulty in executing a task but decrease the frequency of doing the task or modify the task/environment. In a follow-up study Fried and colleagues, it was found that 16% of healthy older adults reported decreased frequency or modified behavior in driving (Fried et al., 1996). While these older adults may have perceived their functional changes and adopted some modifications, it is not clear whether their self-awareness was accurate. Inaccurate self-awareness could lead to inappropriate adoption of task modification and compromise their everyday functional performance in terms of effectiveness and safety.

1.4.3 Measurement of self-awareness

Considering the importance of the accuracy of one's self-awareness for task performance, how can it be adequately measured? To date, several measurement approaches have been identified and used in research and clinical settings, and they could be categorized into the following four types: a) comparison between the client's self-ratings of abilities and an informant (e.g. caregivers, health care professionals) using questionnaires ; b) comparison between the clients' prediction on performance and the actual performance (e.g. results on neuropsychological tests or observation of actual behavior); c) structured interviews to compare clients' insight into their own deficits, impacts of deficits on their everyday activity, and goal setting with health care professionals' judgment; d) observing clients' ability to detect and correct errors during or after task execution (Fleming, Strong, & Ashton, 1996; Gillen, 2009; Pachana & Petriwskyj, 2006; Sohlberg, 2000; Sundström, 2007; Toglia & Kirk, 2000).

To determine the accuracy of self-awareness, all of these approaches collect clients' subjective estimation of their own ability, compare their answers with an objective reference, and examine the extent of concordance between the two measures. Each approach present advantages and limitations. For example, comparing clients' and informants' responses to the same questionnaire about the client's ability ensures that both respondents are rating the same target of clinical functioning or performance, and is the most common approach used in clinical settings (Fleming et al., 1996). However, informants' estimation of the client's ability may not be correct.

Caregivers' rating is likely to be influenced by their feelings and mood resulting from caregiver burden and stress (Martyr, Nelis, & Clare, 2014; Razani et al., 2007) and clinicians' ratings may be influenced by the client's diagnosis or sociodemographic status and a lack of an in-depth understanding of the client's condition (Malec, Machulda, & Moessner, 1997). On the other hand, using clients' actual performance as the objective reference avoids the risk of subjective bias from informants' rating, however the client may not rate his or her performance on the same condition as that being assessed in a neurological test or a performance-based assessment (Bandura, 1997; Toglia & Kirk, 2000). For instance, a client may rate his or her mobility based on the performance at home, but the 'actual' mobility ability is assessed by balance assessments or standardized walking tests in the clinical setting. This mismatch between conditions evaluated in the subjective and objective measures could lead to biases in assessing one's accuracy of self-awareness. Structured interviews conducted by health care professionals, such as the Self-Awareness of Deficits Interview (Fleming et al., 1996), asks clients to verbally express the differences in functional abilities, activities of daily living, and life goals before and after an accident or a hospital admission. Clinicians rate the client's self-awareness based on how realistic their answers are. This type of interview would only be appropriate for clients with a sudden change in functional ability, such as clients with stroke or acquired brain injury, rather than for healthy older adults with gradual aging and functional decline. Finally, observing client's ability of error detection and correction is an emerging method to assess self-awareness, since recognizing errors and adopting strategies to adjust performance require a certain level of awareness of task performance (Hart, Giovannetti, Montgomery, & Schwartz, 1998). However, this approach relies on a different type and mechanism of self-awareness, called "on-line awareness", which is usually evaluated by close behavior observations during the task execution or by asking clients to reflect on their errors after the task execution. In contrast to the other three self-awareness assessment approaches, this assessment approach of self-awareness is highly task- and context-dependent (For review, see Toglia & Kirk, 2000).

There is no gold standard to measure the accuracy of self-awareness (Gillen, 2009). Researchers and clinicians must choose an appropriate measurement approach while considering the evaluation purpose, feasibility, effectiveness, and cost, as well as understanding the limitations of the selected approach.

1.5 SELF-AWARENESS OF DRIVING ABILITY AMONG OLDER DRIVERS

In this dissertation, self-awareness as defined by Clair et al. (2008) is applied to the 'object' of driving ability. The accuracy of self-awareness of driving ability is defined as the congruence between an individual's perceived and actual driving ability. The literature related to older drivers' self-awareness of driving ability will be reviewed. The scope of this review is limited to older drivers experiencing a normal aging process and excludes studies which recruited drivers with neurological or neurodegenerative diagnoses, such as mild cognitive impairment, dementia, stroke, traumatic brain injury, Parkinson's disease, and multiple sclerosis. The impaired self-awareness among drivers with these conditions may be caused by their pathological conditions in the nervous system and may be different from older drivers with typical aging. Studies examining older drivers' self-awareness of driving-related functional ability, such as visual (Anstey & Smith, 2003; Holland & Rabbitt, 1992), motor (Molnar et al., 2014), or cognitive function (Holland & Rabbitt, 1992; Meng & Siren, 2012); hazard perception of potential risk on the road (Horswill et al., 2008; Horswill, Anstey, Hatherly, Wood, & Pachana, 2011), driving behavior or style (e.g. aberrant driving behavior measured using the Driver Behavior Questionnaire) (Koppel et al., 2018) are also excluded.

Twelve studies fit the inclusion criteria of this review (Broberg & Dukic Willstrand, 2014; Brown et al., 2005; Freund et al., 2005; Hunt, Morris, Edwards, & Wilson, 1993; Koppel et al., 2016, 2017; Marottoli & Richardson, 1998; Okonkwo et al., 2009; Riendeau, Maxwell, Patterson, Weaver, & Bedard, 2016; Selander et al., 2011; Wild & Cotrell, 2003; Wood, Lacherez, & Anstey, 2013), including four articles that recruited healthy older adults without cognitive impairments as their control group (Brown et al., 2005; Hunt et al., 1993; Okonkwo et al., 2009; Wild & Cotrell, 2003). All were cross-sectional studies, except Koppel et al. (2017), which examined the relationships between changes in perceived and actual driving ability over one year.

Some studies have examined the correlation between perceived driving ability and actual driving performance among a cohort of older drivers (n =227; mean age = 81.5 years) from the Ozcandrive study (Koppel et al., 2016, 2017). The results are mixed. Koppel et al. (2016) showed that older drivers who made more driving errors perceived themselves as having worse driving ability, indicating that they were aware of their declining driving ability. However, in their longitudinal study that examined the association between changes in perceived and actual driving ability over one year, no such linear relationship was found (Koppel et al., 2017).

Other studies have reported the percentage of older drivers who rated themselves as average, good, or very good drivers, but failed an on-road driving evaluation or on a driving simulation test, made more errors during an on-road evaluation, or had crash history (Brown et al., 2005; Freund et al., 2005; Hunt et al., 1993; Marottoli & Richardson, 1998; Riendeau et al., 2016; Selander et al., 2011; Wild & Cotrell, 2003; Wood et al., 2013). Interestingly, two studies recruited healthy older drivers as the control group (n=25 and 13, respectively) and reported that 77%-100% of these drivers rated themselves as good or safe drivers and all passed the on-road driving evaluation, indicating they under-estimated or accurately-estimated their self-awareness of satisfactory driving ability (Brown et al., 2005; Hunt et al., 1993). Another study with a healthy control group (n=15) showed that healthy older drivers over-estimated their driving ability in “managing intersections”, but under-estimated their abilities in “handling conversational distraction” (Wild & Cotrell, 2003). The studies which included only healthy older drivers showed consistent results of over-estimation of driving ability among at-risk older drivers (n=33-85) (Freund et al., 2005; Marottoli & Richardson, 1998; Riendeau et al., 2016; Selander et al., 2011; Wood et al., 2013). Almost all the older drivers who failed the on-road driving evaluation rated themselves the same, better, or a lot better than other drivers of the same age or as having average, good, very good to excellent driving ability (Freund et al., 2005; Marottoli & Richardson, 1998; Riendeau et al., 2016; Selander et al., 2011; Wood et al., 2013). Freund et al. (2005) reported that drivers who rated themselves as slightly better than the other drivers of the same age are four times more likely to fail the driving test than those who rated their driving ability as the same or worse. Selander et al. (2011) used a refined scale to assess older drivers’ perception of driving ability and found that older drivers who failed the driving test rated themselves as having worse driving ability than those who passed the on-road evaluation; despite this, most of the participants rated themselves better than other drivers of the same age, regardless of whether they passed or failed the on-road driving evaluation.

Finally, some studies have compared the concordance between the measurements of perceived and actual driving ability using cut-off scores and reported the proportion of under-, accurate, and over-estimating groups (Broberg et al., 2014; Okonkwo et al., 2009). Okonkwo et al. (2009) assessed the self-awareness of 68 healthy older drivers’ by comparing their self-rated driving difficulty and ability in five driving conditions to their performance during a standard on-road driving evaluation rated by a certified driving rehabilitation specialist. The results of their perceived and actual driving ability were dichotomized as 0 = no difficulty in self-rated driving ability or optimal on-road driving performance and 1 = some difficulty in self-rated driving ability or less than optimal on-road driving performance. By calculating the discrepancy score (actual-perceived), the authors reported that the percentages of older drivers who under- (discrepancy score = -1), accurately (discrepancy score = 0), and over-estimated (discrepancy score = +1) their driving ability were approximately 14%, 57%, and 30%, respectively. Broberg et al. (2014) used a semi-structured interview to assess older drivers' perception of driving ability (e.g. do you think you are a good driver compared to other people of your age?) and rated perceived driving ability as good or poor based on their response. Participants' on-road driving performance was evaluated using a dual-brake vehicle in a familiar area. The route was guided by the driving instructor sitting in the front passenger seat. Drivers were asked to drive as they normally do and their driving behaviors were recorded by an occupational therapist sitting in the car using a standard protocol. Participants' driving performance was classified as good (52.5%) and poor (47.5%) using the median error score of the sample. The authors illustrated a two by two table to show the correspondence between perceived and actual driving ability: 8% of the older drivers under-estimated their driving ability, and 38% of the drivers over-estimated their driving ability. Drivers who can accurately estimate their driving ability were grouped into those who had good driving ability (41%) and poor driving ability (13%).

The different approaches used to investigate older drivers' self-awareness of driving ability provide useful information for our understanding of older drivers' awareness of their driving ability. The results of the correlational studies (Koppel et al., 2016, 2017) which found mixed results between perceived and actual driving ability, may indicate that some older drivers over-estimated while others under-estimated their driving ability. This would results in a non-linear relationship between perceived and actual driving ability. The second type of studies focused on older drivers who may be more at risk since they failed the on-road driving evaluation but rated themselves as good drivers. The findings report on at-risk older drivers who over-estimated their driving ability, however, the characteristics of drivers who under-estimated their driving ability were not reported. The last approach clearly categorized older drivers into under-, accurate, and over-estimation groups, but these studies did not explore the characteristics (e.g. age, gender, or cognitive functioning) of older drivers with different levels of accuracy of driving ability.

There are several methodological issues related to the measurements used in these studies of self-awareness of driving ability. For the assessments of perceived driving ability, the two major flaws are the ambiguity of using general questions and the phenomenon of "social comparison". These problems are likely to lead to biased, especially high ratings, of one's perceived driving ability. For the measurement of driving, most studies used the standard on-road driving evaluation. This evaluation approach is considered to be the gold standard to evaluate a driver's on-road driving ability (Di Stefano & MacDonald, 2006), but it tests participants in an unfamiliar situation (e.g. vehicle, guided route, and unfamiliar driving area). The results may not be representative of everyday driving performance. Nevertheless, another new on-road driving evaluation approach, the naturalistic driving observation, may have better ecological validity over the standard on-road driving ability to illustrate older drivers' common driving behaviors and environments, including their self-regulatory behaviors. The following sections will discuss the assessments used for evaluating the perceived and actual driving ability and highlight the need to adopt the best possible approach for measuring older drivers' accuracy of self-awareness of driving ability.

1.6 MEASUREMENT OF SELF-AWARENESS OF DRIVING ABILITY

1.6.1 Measurement of perceived driving ability

To measure older drivers' perceived driving ability, several studies used only a single question to assess drivers' self-perception of driving ability (e.g., rate the quality of your driving) (Brown et al., 2005; Wild & Cotrell, 2003; Wood, Lacherez, & Anstey, 2013), or used questionnaires that were not specifically designed for driving. For example, the Deficit Awareness Questionnaire that measures one's perceived abilities in memory, attention, and everyday activities was administered to investigate older drivers' self-awareness of driving performance (Wild & Cotrell, 2003). Although these questions address aspects of driving ability, they are not likely to guide an individual to reflect on their driving performance in different driving conditions and respond specifically about their driving abilities. Several researchers recommended that while assessing perceived driving ability, providing contextual details about specific driving maneuvers and environments could guide clients to better reflect on their driving ability (Molnar et al., 2013; Sundström, 2007; Wong et al., 2012).

Some studies assessed older drivers' self-perception of driving ability by asking them to compare their driving competence to others, either drivers of the same age or all drivers on the road (Broberg & Dukic Willstrand, 2014; Freund et al., 2005; Selander et al., 2011). This type of question requires an individual to appraise both their own ability and others' abilities, and then make a 'social' comparison. Literature in cognitive psychology has found that a better-than-the-others answer is common in human nature (Reisberg, 2013). Several theories have been published to explain this phenomenon, including optimism bias, self-enhancement bias, downward comparisons, and illusory superiority (Groeger, 2000; Sundström, 2008). Approximately 70% of older drivers perceive their driving ability to be better than others' (Marottoli & Richardson, 1998; Selander et al., 2011), even though some participants were recruited from driving rehabilitation clinics where their driving ability had already been questioned (Freund et al., 2005). Questions that involve social comparisons can lead to inaccurate judgement of one's own ability, and, therefore, may not serve as the best means of capturing an older drivers' subjective measure of driving ability.

It is important to adopt a reliable and valid questionnaire specifically designed to assess older drivers' perception of driving ability. Several tools are available for use with older drivers. Amongst those, one questionnaire is only suitable for clients referred to driving rehabilitation centres (i.e. DriveAware) (Kay, Bundy, Clemson, & Jolly, 2008), while others were only tested with clients with neurological conditions (i.e. Brain Injury Driving Self-Awareness Measure for clients with brain injury and Adelaide Driving Self-Efficacy Scale for clients with stroke) (George, Clark, & Crotty, 2007; Gooden et al., 2017) or younger adults (Driving Skill Inventory (Lajunen & Summala, 1995), Driving Self-Evaluation Questionnaire (Amado, Arikan, Kaca, Koyuncu, & Turkan, 2014), and Self-Efficacy Scale for Driver Competence (Sundström, 2008)). To date, only the Perceived Driving Ability Questionnaire (PDA) has been validated with a group of older drivers using an on-road driving observation protocol, which showed that older drivers with better driving performance rate their ability higher than poor drivers (Koppel et al., 2016) (see Appendix 1).

1.6.2 Measurement of actual driving performance

To assess the accuracy of older drivers' self-awareness of driving ability, their self-perception of driving ability must be compared to some measure of actual driving performance. This can include the standard on-road driving evaluation (Broberg & Dukic Willstrand, 2014; Brown et al., 2005; Hunt et al., 1993; Marottoli & Richardson, 1998; Okonkwo et al., 2009; Riendeau et al., 2016; Selander et al., 2011; Wild & Cotrell, 2003; Wood, Lacherez, & Anstey, 2013), a naturalistic driving observation (Koppel et al., 2016, 2017), or a driving simulation test (Freund et al., 2005).

The following section will briefly review the approaches of standard on-road driving evaluation and the naturalistic driving observation. Driving simulation tests were excluded because older adults are more likely to suffer from simulator sickness than younger drivers (Brooks et al., 2010), and their ecological validity to represent actual driving performance is still questionable (Casutt, Martin, Keller, & Jäncke, 2014).

Standard on-road driving evaluation (SODE). The SODE has long been considered as the gold standard to examine fitness-to-drive by clinicians in the field of driving evaluation and local traffic authorities (Kowalski, Tuokko, & Tallman, 2010; Odenheimer, Bearudet, Fette, Albert, Grande, & Minaker, 1994; Ott, Papandonatos, Davis, & Barco, 2012). Serving as a discriminative evaluation tool, the SODE has gradually developed into a highly-structured approach with validated psychometric properties, pre-defined procedures and driving routes, targeted behavioral recording items, and scoring scales to systematically interpret and judge driving ability (Justiss et al., 2006; Wood et al., 2009). During SODEs, clients are asked to drive an instrumented car with a dual brake for the driving instructor, who sits at the passenger seat, to take control of the car when necessary. Clients' driving route and maneuvers are guided by the driving instructor to keep the driving environment consistent between clients or across evaluation sessions. Drivers' behavior is usually recorded by a specialized occupational therapist sitting in the backseat using a standardized evaluation form (Di Stefano et al., 2006).

The SODE protocol is commonly used in clinical settings. However, older drivers' self-regulatory behaviors in their everyday living cannot be demonstrated during the SODE. The routes included in the SODE may over-challenge their driving ability if the driver has already avoided driving in some difficult conditions, such as highways. In addition, an older drivers' performance could be negatively influenced by the unfamiliar car and driving environment due to anxiety (Bhalla, Papandonatos, Stern, & Ott, 2007; Fairclough, Tattersall, & Houston, 2006; Lundberg & Hakamies-Blomqvist, 2003; Uc et al., 2009) or increased mental workload for adapting to the new car and task (Berndt, May, & Clark, 2006; Engstrum, Johansson, & Ostlund, 2005; Shinar, Meir, & Ben-Shoham, 1998). These are limitations that may influence older drivers' performance during a SODE.

Naturalistic driving observation (NDO). The NDO was designed to observe and record drivers' on-road behavior in their everyday driving environment with a minimum level of interference (Backer-Grøndahl, 2009; Valero-Mora et al., 2013). During the NDO, clients drive their own car from home to their selected destinations on routes familiar to them. They are asked to drive as they normally do, such as talking with passengers or listening to the radio. This drive simulates older drivers' driving trips that are purposeful and meaningful in their everyday living. The drivers' behavioral and related environmental factors are captured using in-car recording devices, such as cameras, global positioning systems (GPS), or engine data recording instruments, and/or observers sitting in the driver's car or in a following car (Ott et al., 2012). The NDO drive is considered a representative sample of the driver's everyday driving, or the "reality" of an individual's driving performance (Eby, 2011).

Older adults' driving performance during a NDO may be different from their performance during a SODE since they are asked to demonstrate their everyday driving behavior on a route they choose within their familiar environment. It is possible that some older drivers who fail the SODE could demonstrate good driving performance during a NDO by choosing to drive on quiet streets to reach their destinations. Since older adults' driving performance is measured and used to compare with their perceived driving ability to determine the accuracy of self-awareness of driving ability, the choice of evaluation context would have an important impact on the outcome.

1.7 FACTORS ASSOCIATED WITH SELF-AWARENESS OF DRIVING ABILITY

Few studies have investigated the characteristics of healthy older drivers who over-, accurately, or under-estimated their driving ability. Older age was found to be related to over-estimation of driving ability (Marottoli & Richardson, 1998). One study reported that older drivers with better cognitive functioning and executive functioning tended to be accurate or under-estimate their driving ability (Wood et al., 2013), however, two other studies did not find any relationship between the cognition and accuracy of self-awareness (Broberg & Dukic Willstrand, 2014; Freund et al., 2005). These inconsistent results may be related to varied methods used to measure actual and perceived driving ability.

Several studies have explored factors associated with older drivers self-perception of driving ability and self-regulatory behaviors. For example, being female is found to be linked to lower perceived driving ability (Selander et al., 2011), more avoidance of difficult driving conditions, and earlier driving cessation compared to male older drivers (Foley, Heimovitz, Guralnik, & Brock, 2002; Charlton et al., 2006; D'Ambrosio et al., 2008; Kostyniuk & Molnar, 2008; Rimmö & Hakamies-Blomqvist, 2002). Older drivers with better psychomotor processing speed and executive function are likely to perceive themselves as having better driving ability and avoiding fewer complex driving conditions (Lajunen, Corry, Summala, & Hartley, 1998; Rapoport et al., 2013; Rapoport et al., 2016). However, the relationship between gender and executive functioning with older drivers' accuracy of self-awareness of driving ability remains unclear.

1.8 SUMMARY

The number of older drivers in developed countries is rapidly growing; their need and desire to use a car for outdoor mobility in their later age is high. However, their driving ability may be diminished due to age-related functional decline and medical conditions, leading to higher crash risk. This literature review focused on why older drivers' accuracy of self-awareness of their driving ability is an important factor to enable the adoption of appropriate self-regulatory behaviors and maintenance of safe driving behaviors for as long as possible. Current gaps regarding older drivers' self-awareness of driving ability were also identified.

The DEC model suggested that "moderators", including beliefs, self-awareness, self-monitoring, and self-efficacy, could influence older drivers' everyday driving performance regardless of actual driving ability (Lindstrom-Forneri et al., 2010). While many older drivers adopt self-regulatory behaviors, and this practice is effective to help decrease crash risk (Charlton et al., 2006; Hakamies-Blomqvist, 1994; de Raedt & Ponjaert-Kristoffersen, 2000), many studies found that older drivers' self-regulation is largely driven by their perceived driving ability, rather than their actual driving ability (Ackerman et al., 2010; Baldock et al., 2006; MacDonald, Myers, & Blanchard, 2008; Rapoport et al., 2013; Wong, Smith, & Sullivan, 2012).

Older drivers' perceived driving ability may be inaccurate, leading to insufficient or inappropriate use of self-regulatory behaviors (e.g. premature driving cessation or lack of self-regulation) (Ross et al., 2009). The accuracy of self-awareness, which measures the concordance between one's perceived and actual driving ability, could be a crucial factor to determine older drivers' on-road safety in their everyday driving. Some studies have examined this topic, but due to methodological issues, the findings may not be valid. For example, the measurement of perceived driving ability may be inaccurate due to the selection of tools that are based on unclear "object" description and "social comparison". In addition, most studies adopted standard on-road driving evaluations to assess older drivers' driving ability, which may not represent their everyday driving environment and behavior. Also, studies examining the characteristics of older drivers who under-, accurately, and over-estimated their driving ability were scarce, the findings were not consistent, and no longitudinal studies have been published. The studies presented in this dissertation were administered to examine and clarify these questions related to older drivers' self-awareness of driving ability, both cross-sectionally and over one year.

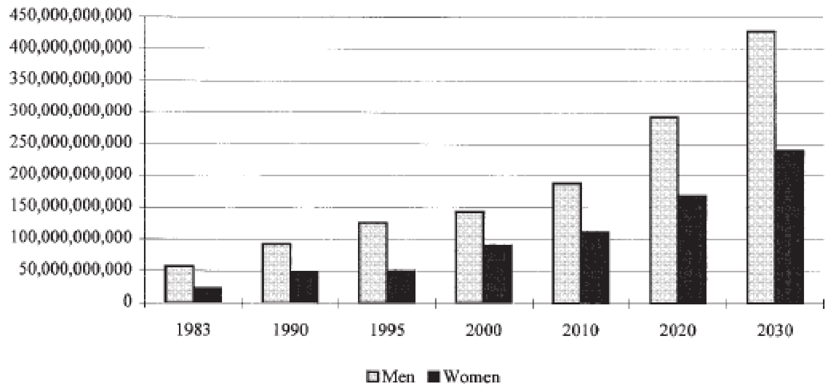

Figure 1.1 Actual and projected total annual miles driven in men and women, from 1983 to 2030. Reprinted from “Tomorrow’s older drivers: Who? How many? What impacts?”, by J. E., Burkhardt & A. T. McGavock, 1999, *Transportation Research Record, 1693*, 62-70.

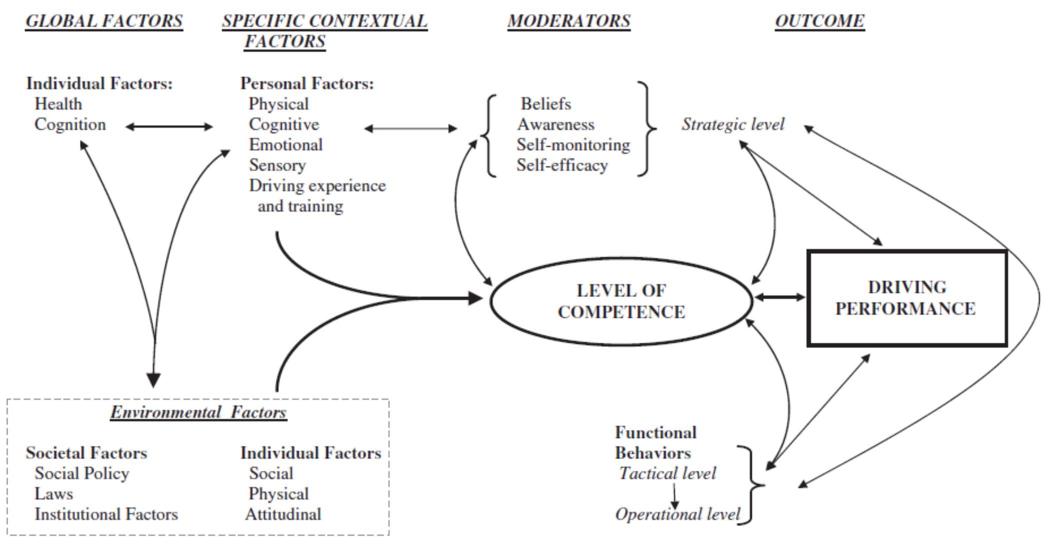

Figure 1.2 Driving as an Everyday Competence (DEC) model. Reprinted from "Driving as an everyday competence: A model of driving competence and behavior", by W., Lindstrom-Forneri, H. A., Tuokko, D. Garrett, & F. Molnar, 2010, *Clinical Gerontologist*, *33*, 287-297.

CHAPTER 2: RATIONALE AND OBJECTIVES

2.1 STUDY RATIONALE

Older drivers' self-awareness of driving ability in their naturalistic driving environment may be a key factor to influence their everyday driving safety through stimulating appropriate use of self-regulatory behavior. However, this topic is still not clearly understood in the current scientific literature.

The accuracy of self-awareness is defined as the concordance between perceived and actual ability. In driving, one methodological issue comes from the objective measurement used to determine how accurately older drivers perceive their driving ability. Two different on-road approaches, the standard on-road driving observation and the naturalistic driving evaluation, can be utilized. Since these methods have never been compared, an in-depth comparison is needed to determine how these different approaches influence the assessment of an older adult's driving performance and to guide the choice of the most appropriate method for judging older drivers' self-awareness. Most studies administered a standard on-road driving evaluation to evaluate older drivers' actual driving ability, however, the controlled and structured evaluation context limits its validity to represent their everyday driving performance. In this dissertation, older adults' driving performance in their everyday driving environment was assessed using a novel naturalistic driving observation approach.

The naturalistic driving observation approach used in this thesis is the electronic Driving Observation Schedule (eDOS). This tool was developed and validated to observe and monitor older adults' driving behavior in their everyday driving environment. The original eDOS total score was generated by the proportion of appropriate maneuvers over the total number of maneuvers recorded. This formula did not consider that driving errors could have different levels of risk. Some errors are more serious than the others, depending on its type, driving maneuver, and the environmental complexity in which it occurs. To better describe the complexity of the maneuver/environment and to better represent older drivers' performance using driving error recordings, it was necessary to create weighted scores for systematically quantify the complexity of environment and providing weights to each error according to its risk level.

After generating the weighted eDOS scores, older drivers' self-awareness of driving ability in naturalistic driving environment could be examined by comparing the correspondence between their perceived and actual driving performance. As emphasized in the literature review, categorizing accuracy of self-awareness into under-, accurately, and over-estimation of driving ability is advantageous to investigate the characteristics (i.e. demographic information and clinical functioning) of older drivers in each group. Previous studies have never used a naturalistic driving observation approach to investigate this topic. Findings from this study will inform clinicians about self-awareness and the associated clinical factors related to inaccurate self-awareness of driving ability. It will also assist them in tailoring their training programs to address perception of driving.

To date, how older drivers perceive and monitor their driving ability in their naturalistic driving environment over time has not been studied. Understanding their accuracy of self-awareness of changes in driving ability may help clinicians to detect those who may have the tendency to over- or under-estimate their driving ability. A longitudinal study is needed to describe the proportion and characteristics of older drivers who can and cannot accurately monitor their changes in driving performance.

2.2 STUDY OBJECTIVES

The overall study objective of this PhD dissertation is to contribute evidence toward older drivers' self-awareness of driving ability in their naturalistic driving environment. To reach this goal, specific research objectives are:

1. To compare and contrast the standard on-road driving evaluation and the naturalistic driving observation approaches, using the Person-Environment-Occupation (PEO) model.

   Manuscript #1 (Chapter 3): Determining Older Adults' Fitness-to-Drive: Comparing the Standard On-Road Driving Evaluation and the Naturalistic Driving Observation

2. To generate a score to represent the complexity of the driving route chosen by the client during the naturalistic driving observation (i.e. the eDOS) and to develop a scoring and

weighting scale for the eDOS total score accounting for the severity of driving errors and complexity of maneuvers in their corresponding environments.

Chapter 4: Development of a weighted scoring system for the eDOS

3. To determine the accuracy of older drivers' self-awareness of driving ability in their everyday driving environment, and to determine the relationship between demographic characteristics (i.e. age, gender, and educational level) and clinical factors (i.e. visual, cognitive, psychomotor and executive functioning, mood, comorbid medical conditions) with self-awareness of driving ability.

   Manuscript #2 (Chapter 5): Personal and clinical factors associated with older drivers' self-awareness of driving performance

4. To describe older drivers' self-awareness of changes in driving ability over one year, and to determine the association between self-awareness and demographic characteristics and changes in clinical functioning.

   Manuscript #3 (Chapter 6): Longitudinal changes in older drivers' self-awareness of driving ability

CHAPTER 3: MANUSCRIPT #1

Determining Older Adults' Fitness-to-Drive: Comparing the Standard On-Road Driving Evaluation and the Naturalistic Driving Observation

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3.1 Abstract

Aims: An older adult's on-road driving performance could be assessed by two different approaches, namely, the standard on-road driving evaluation (SODE) and the naturalistic driving observation (NDO). This paper aims to compare the SODE and the NDO approaches using the person-occupation-environment model, to improve clinicians' reasoning when choosing an appropriate approach for older drivers. Methods: A reflective review of the literature was used to evaluate the features of these two approaches. Results: During the SODE, driving capacity is examined in a controlled condition using predetermined driving maneuvers, routes, and vehicles which may be unfamiliar. In contrast, during the NDO, an older adult's driving competence is evaluated in the driver's everyday driving environment and vehicle with minimum interference. The limitations of each approach are discussed. Conclusions: The SODE and NDO approaches evaluate an older adult's driving capacity (i.e., personal ability) and competence (i.e., the fit of person-occupation-environment components) in different ways.

Keywords: automobile driving, behavior observation, assessment, evidence-based practice

3.2 Introduction

Many older adults drive their private vehicle as their primary mode of transportation to commute between home, work, and community leisure and social activities. Driving contributes to maintaining one's autonomy and independence, and facilitates their daily engagement and participation in life roles. For older drivers in North America, driving is of particular importance, because compared to other forms of mobility (e.g., walking, taking public transportation, asking for a ride), it is thought to be safer, more convenient, and is the preferred mode of transportation for community mobility (Sleightholm et al., 2010). With the increasing population of older adults, older drivers' safety on the road is a growing concern for society (Eby et al., 2009).

According to police-reported crash data in the United States, older drivers have a higher crash rate per distance driven compared to middle-aged drivers (Cicchino et al., 2014). This finding has been explained in two ways: 1. older adults' medical conditions and age-related functional decline increase their probability of crash involvement (Anstey et al., 2005) and 2. older adults' fragile body structure is less able to tolerate the impact of a crash and this elevated severity of the consequences results in a greater number of severe injuries, hospitalizations, and deaths compared to younger drivers (Meuleners et al., 2006).

Many jurisdictions have implemented different strategies to reduce these adverse consequences of automobile crashes. One of the most drastic solutions is to revoke the driver's license, eliminating an at-risk driver's exposure to driving. This solution may be simple for the public, but, for the individual, losing the privilege of driving is usually associated with a plethora of negative psychosocial effects, including a decrease in the type and frequency of out-of-home social activities (Marottoli et al., 2000), increased depressive symptoms (Ragland et al., 2005), and increased family burden (Taylor et al., 2001). A more mindful solution, which balances the individual and collective requirements, is needed.

The prevailing approach to addressing the issue of at-risk older drivers is to examine their driving capacity and performance. A comprehensive approach including a review of the client's medical and driving-related history, the administration of a series of in-clinic assessments, and an on-road driving evaluation, is considered the best-educated judgement of fitness-to-drive (Hakamies-Blomqvist 2006). Furthermore, because there is no single or combination of in-clinic assessments that can fully predict or explain the occurrence of one's crash involvement, the standard on-road driving evaluation (SODE), with high face validity, is commonly considered the gold standard for the determination of fitness to drive (Dickerson et al., 2014).

The purpose of the SODE is to examine one's driving capacity, defined as the extent to which the client could efficiently and effectively integrate their driving knowledge and skills, such as scanning, selective attention, motor control, judgment, decision making, and knowledge of traffic signs and rules, to drive safely in real-life settings (Di Stefano et al., 2006). Serving as a discriminative evaluation tool, the SODE has gradually developed into a highly-structured approach with improved psychometric properties, pre-defined procedure and driving routes, targeted behavioral recording items, scoring scales, and approaches of interpreting driving performance (Justiss et al., 2006; Wood et al., 2009). These protocols enable the evaluators to simultaneously observe and record one's driving performance, also ensure test consistency and fairness across clients or evaluation sessions (Di Stefano et al., 2006).

The design of most SODE protocols follows professional guidelines while the driving routes and maneuvers are adapted to local contexts in each driving rehabilitation centre (DRC). A typical SODE is administered under the condition of moderate traffic volume on a clear day. A dual-brake instrumented vehicle is used, allowing the driving instructor to break or intervene whenever necessary to ensure safety during the evaluation. The drive begins at the DRC, and continues onto a wide range of route types consisting of parking areas, quiet residential streets, city boulevards, and highways for a duration of 45 to 60 minutes, following the direction instructions given by the driving instructor sitting in the front passenger seat. During the drive, the maneuvers that older drivers typically have difficulty are tested. For instance, according to a Canadian Consensus, four-way stop intersections, yield situations and left turns are items that should be included in a SODE (Korner-Bitensky et al., 2005). The client's driving behaviors are observed and recorded by a trained clinician sitting in the back-right seat. The recording of the driver's behaviors includes the clinician's overall impression of the driver's performance, such as awareness of the driving environment, rapid decision making, as well as detailed scoring of each of the driver's actions, including turning, merging, and lane changing (Di Stefano et al., 2006). After completing the drive, the clinician analyzes the client's performance in collaboration with the driving instructor's opinions, and makes the final recommendations about the client's driving safety to the local license administration. In summary, the SODE is a comprehensive evaluation approach which assesses a driver's ability to handle a representative sample of driving conditions and maneuvers.

The SODE protocol has evolved over time. Some clinicians adopt a component self-directed driving into the SODE. The driver is asked to search and follow road signs to reach a target destination or to find target landmarks without any route guidance from the driving instructor. This component simulates a way-finding, self-navigating or target searching task that is common when people drive into an unfamiliar area, and is recommended as a critical element of a SODE for assessing higher executive function, such as making quick decisions, problem solving, and planning (Mallon et al., 2004). Mallon and Wood (2004) reported that drivers of all ages make more errors during a self-directed drive than a guided one. With older age and more impaired visual function, the difference in driving performance between the guided and self-directed components increases.

While the SODE is commonly administered in most jurisdictions in developed countries, another approach, the naturalistic driving observation (NDO), may provide a different point of view of older drivers' fitness-to-drive. The naturalistic observation was a research methodology derived from sociopsychology and sociology to understand human or animal behaviors with minimum interference or disturbance. It was adapted by researchers in traffic psychology to investigate people's driving behavior in everyday environment (Backer-Grondahl et al., 2009).

Recently, researchers in rehabilitation science have identified the potential of using the NDO to evaluate older adults' everyday driving competence. Many older adults modify their driving in response to declining driving abilities, such as modifying their schedule to avoid unpleasant and complex driving conditions (e.g., heavy rain at night) (Baldock et al., 2006), driving shorter distances from home (Donorfio et al., 2008), driving slower on quieter routes, and maintaining a greater following distance. Literature suggests that these defensive, self-regulated driving behaviors can effectively protect older drivers from crashes (de Raedt et al., 2000). While these modifications are critical to maintain driving safety and preserve personal and social functions, it is not possible for older drivers to utilize these strategies during a SODE (Lundberg et al., 2003). In contrast, during an NDO, the self-regulatory behaviors could be observed and further analyzed to understand their impacts on an older driver's everyday driving performance.

During the NDO, clients drive their own car from home to their selected destinations on their familiar routes. This drive simulates the daily driving trips that are purposeful, meaningful, and familiar to the person. The drivers' behavioral and related environmental factors are captured using in-car recording devices, such as cameras, global positioning systems (GPS), or engine data recording instruments, and/or observers sitting in the driver's car or in a following car with a minimum level of interference to the driver (Ott et al., 2012). The NDO is considered to be a representative sample of the driver's everyday driving profile, or the "reality" of an individual's driving performance (Eby 2011).

To date, there are no publications describing the pros and cons of the SODE and the NDO evaluation approaches, while this information is necessary for clinicians to determine when one approach may be more appropriate to administer than the other. The purpose of this article is to compare and contrast the SODE and the NDO approaches, using the Person-Environment-Occupation (PEO) model (Law et al., 1996). This model was selected because it explains the interactions between the person, environment and occupation (driving) components that clinicians must examine when determining one's fitness-to-drive and addresses the change in performance over time. According to the model, the three main components are presented by three circles (figure 3.1). A larger overlapping area between these circles indicates a better "fit" or a higher level of harmony between the components, leading to a greater potential of better performance. The overall driving performance is represented by the central overlapping area (the shadowed area). This figure gives an example showing improved driving performance over time by greater person-occupation-environment fit (from figure 3.2a to 3.2b). In summary, through analyzing the differences in the occupational, personal and environmental components between the SODE and NDO approaches, and how the driving performance change over time, this review will attempt to clarify the appropriate clinical use for each, benefiting clinicians by using more holistic reasoning to judge the selection of the best evidence-based evaluation method.

3.3 Comparing the SODE and the NDO using the PEO Model

3.3.1 Occupation

The SODE and NDO both focus on the occupation of driving. Michon's hierarchical model, which categorizes the driving behaviors into three levels, can be used as the structural framework to analyze this task and compare the differences between the two approaches (Michon 1985). According to this model, the driving task is controlled by the driver's cognitive and executive function at three hierarchical levels: strategic, tactical, and operational. The strategic level refers to the pre-planning thoughts and actions of the driver, which influences the complexity of the driving environment. For example, a driver may choose a route to avoid construction and traffic jams, avoid driving in the rain or at night, or prepare a GPS device to navigate in unfamiliar areas. The tactical level is executed during the drive, and involves the quick decisions related to the maneuvers of negotiating the driving environment. For instance, a driver decides to overtake a vehicle, slows down at a school zone, or finds an appropriate gap when changing lanes. Finally, the operational level covers most automatic behaviors of immediate vehicle control, such as signalling, steering and braking, as well as the person's visual-motor and coordination functions.

Strategic level. The task of planning a driving trip in advance is crucial to one's everyday driving performance as it determines the driving complexity, visibility conditions and level of difficulty. Nevertheless, most SODE protocols do not involve drivers' strategic judgement because the purpose of the drive, driving conditions and routes are predetermined by clinicians. Drivers are usually required to exclusively follow the instructions of a driving instructor to demonstrating the driving capacity in a wide range of road types and contexts. The information related to a driver's strategic planning ability is gathered indirectly using an interview, or a self- or proxy-reported questionnaire before the SODE (Dickerson et al., 2014).

On the contrary, the NDO involves the pre-planning for a drive, which means that drivers are required to use their judgement at the strategic level to plan driving trips as they do in their everyday driving. The driver determines the purpose of the trip, when to depart, and how to get to the destinations, while considering their personal health condition, additional driving aids, as well as the weather, traffic and road conditions. In one study that examined 248 older drivers' daily strategic planning using a self-reported questionnaire, approximately half reported that they execute at least one type of strategic planning behavior. These drivers are called self-regulators because they modify and regulate their driving trips towards less complex situations (Molnar et al., 2014). Older drivers with visual, psychomotor, or cognitive functional impairments tend to avoid driving at night, in unfamiliar areas, and on highways more than healthy older adults (Donorfio et al., 2008). Other naturalistic driving studies in older drivers echoed these results by videotaping or gathering vehicle engine data over one to two weeks. Older drivers choose driving conditions that are more familiar, have less traffic volume, and clearer weather (Blanchard et al., 2010). Moreover, some older drivers take advantage of passenger collaboration to drive in unfamiliar areas. One study investigating 194 pairs of older drivers and their regular driving companions reported that around two third of the passengers (usually the spouse) help the driver to plan a trip. Over 80% of the passengers also assist in directing the routes and searching road signs while travelling in unfamiliar areas (Bryden et al., 2014). The NDO serves as an ecologically valid way to examine a driver's daily strategic planning.

The SODE with fixed testing conditions does not directly assess one's strategic planning ability. The indirect information gathered from self-reported methods may be biased and not an accurate reflection of the driver's actual daily performance. Older drivers tend to report that they take fewer trips and drive more frequently in challenging situations compared to the data recorded using in-vehicle recording devices (Blanchard et al., 2010). In contrast, the NDO takes place when a driver determines when and how to reach their destinations, demonstrating the driver's strategic decisions and performance. In addition, the driving condition and route in a SODE is likely to challenge older drivers who have already self-regulated their driving to only drive in less complex driving situations or to rely on assistance from their passenger (Davis et al., 2012). This may lead to an unsatisfactory result in the SODE and cause early driving cessation. In summary, the NDO approach can assess an older driver's strategic planning behaviors more directly and ecologically than the SODE approach.

Tactical level. Driving maneuvers at the tactical level is the focus in both the SODE and NDO approaches because it directly demonstrates a driver's instant judgements and potential risk in traffic (Dickerson et al., 2014). This similarity is presented in their common targeted behavioral recording items, such as speed control at an intersection and gap selection at a merging maneuver.

Nevertheless, the two approaches differ in the environment where the skills at the tactical level are demonstrated and the involvement in a dual-task. During a SODE, the location in which drivers must demonstrate their tactical maneuvers and skills are controlled by the clinician. For example, a driver is guided to make a left turn at an unprotected intersection in moderate traffic or merge into highway traffic. During the self-directed driving component, the maneuvers and skills needed to reach a designated destination are examining a driver's ability to develop an efficient plan, read road signs, and execute the plan to reach the goal effectively in an unfamiliar area. On the other hand, the NDO does not have a structured context to evaluate an older driver's tactical skills, leaving a wide window for drivers to independently determine their actions while driving. Like the strategic skills, drivers could avoid some complex driving maneuvers and environments at the tactical level, such as avoiding merging into high-speed traffic. The overall level of difficulty of the drive at the tactical level may be simpler if a driver intentionally avoids these actions.

In addition, drivers' involvement in a dual-task may be demonstrated during a NDO, whereas secondary task involvement is controlled and limited during a SODE. In fact, there is a large range of secondary tasks that drivers commonly engage in during a drive, such as grooming, changing the radio station, checking the instructions on the GPS device, talking on a hands-free phone or with passengers (Prat et al., 2015). Although some of the secondary tasks are not directly associated with a driver's reaction to the traffic, and are not directly related to tactical vehicle control, they are important factors impacting a driver's arousal level, mental workload, and attention during a drive (Horberry et al., 2006). Engaging or not in a secondary task could reflect an older driver's self-regulation or compensatory behaviors (i.e., discard a distracting secondary task or drive slower while driving in a challenging condition), and may be a moderating factor to lower an older driver's crash risk (Charlton et al., 2013). This is not directly observed during the SODE.

Operational level. At the operational level, older drivers' performance would be demonstrated as a balance between their rich driving experience and declining body function. On one hand, their driving experience would increase the automaticity of vehicle control, reducing the attention needed for basic vehicle manipulation skills (Ranney 1994). On the other hand, older drivers' visual-spatial attention or psychomotor function may be declining, leading to a higher occurrence of operational errors, such as less visual scanning of the environment and more lateral deviations in vehicle position (Perryman et al., 1996). In both approaches to driving evaluation, a driver's operational driving skills to control a vehicle and scan the environment is performed naturally and similarly, but the unfamiliar vehicle used during the SODE may cause higher workload and less automaticity in vehicle control.

3.3.2 Environment

Environmental factors could have positive or negative influences on one's driving performance. As adults become more susceptible to changes in the environment as they age, the physical and social driving environment could have a critical effect on an older adult's driving competence. The physical environment is defined as "natural and built nonhuman surroundings and the objects in them" (American Occupational Therapy Association [AOTA], 2014) (pp. S28). During a SODE, associated physical features include the factors external to the vehicle, such as geographic location (e.g., urban or rural), precipitation, seasonal variation (e.g., snowy days), light (e.g., daylight or night time), road types (e.g., single or multiple lanes, highway), road conditions (e.g., icy or slushy), traffic volume, speed zones, existence of other road users, as well as factors internal to the vehicle, like the vehicle itself and technological devices (either for the purpose of recording or assisting the driver) installed in the car. The social environment refers to the "presence of, relationships with, and expectations of persons, groups, and populations with whom clients have contact" (AOTA 2014) (pp. S9). The social factors in a driving evaluation comprises the social and psychological influences from passengers and/or evaluators. Since social factors are not usually evaluated in the SODE, this discussion will focus only on the physical factors.

The physical driving conditions change from time to time; some of the changes are unpredictable, while others could be controlled by a pre-drive plan. The unpredictable conditions are random factors that affect a driver's performance similarly whether during a SODE or a NDO. Examples include emergency vehicles passing by or a sudden change of traffic volume due to a crash. The conditions that could be controlled or planned in the two driving evaluation approaches are largely different in terms of who has the right to decide and where the evaluation takes place. During a SODE, clinicians determine the physical driving environment: the driving route starts from the DRC and the driver uses an unfamiliar vehicle equipped with a dual-brake system. On the other hand, the NDO approach gives the client control over the driving environment. The clients drive their own car and the geographical area of observations during the drive are usually centered around their home. Consequently, the environmental familiarity and complexity of driving trips are different in these two approaches.

The familiarity of the environment is one of the most influential factors to an older driver's on-road driving performance. Greater familiarity with the driving environment and the vehicle is associated with less demands in searching relevant environmental cues, memory, and planning (Bryden et al., 2014). It enhances older drivers' automatic vehicle control at the operational level, and decreases the cognitive workload at the tactical level. Past research has shown that older adults perform better processing skills of instrumental activities of daily living (IADL) at home than in an unfamiliar health care clinic (Park et al., 1994). In addition, the impact of environmental unfamiliarity in IADL tasks may be more severe among older adults with visual, cognitive or orthopedic impairments (Provencher et al., 2012). Older drivers can take advantages of automaticity while using their own vehicle, which is likely to eliminate the fundamental errors related to vehicle operation. In one study examining the impact of vehicle used during a SODE, researchers found that 67% of older drivers failed the test using cars with dual brakes provided by the licensing administration, compared to a 51% failure rate using the clients' own car (Lundberg et al., 2003). It is argued that adapting to an unfamiliar vehicle is a secondary task which adds to the complexity of the driving task, so an older driver must place more attention on basic vehicle control skills rather than concentrating on the demands of the driving task during a SODE. In addition, some drivers are accustomed to using assistive technologies installed in their own car, such as a collision avoidance system or a rear-view camera, to help their lane changing or reversing maneuvers. While these assistive devices are not standard equipment in the DRC's car, how an older driver use the technology can be demonstrated ecologically in the NDO. Although some may argue that the recording devices installed on the dash, windshield or side windows during the NDO may distract the driver or influence their visual field, one study reported that drivers tend to concentrate on their driving and neglect the cameras (Ott et al., 2012). Another study conducted a post-drive survey, in which 82% of drivers reported that they are completely at ease with being observed using video camera, and 100% of the participants reported that their driving performance during the observation was about the same as their everyday driving performance

(Vlahodimitrakou et al., 2013). Therefore, the in-car devices installed during the NDO are not likely to change drivers' behavior and performance.

The complexity of the road and the traffic conditions can modify an older driver's performance. It is assumed that through pre-planned routes, the complexity of the SODE administered in different jurisdictions remain consistent. However, the driving conditions during the NDO vary considerably. During the NDO, both the driver's pre-planning decisions of the observational trip (as discussed in the section of strategic level) and the location of the driver's home determine the environment complexity. The location of the driver's home impacts the most on common road and traffic conditions that the driver might encounter. For example, an older driver who lives in a rural area is more likely to drive on roads with a moderate to high speed limit with lower traffic volume, whereas an older driver living in a city centre may commonly experience higher traffic volume and more road users in their everyday driving. In brief, compared to the SODE, the NDO takes place in the area where the driver is more familiar with, and the complexity of driving environment reflects greater individual differences in terms of personal strategic planning and living areas.

3.3.3 Person

The personal component includes an individual's physical, cognitive, affective, and spiritual features (Boyt Schell et al., 2014). In a comprehensive driving evaluation, the commonly considered personal factors include a client's demographic characteristics (e.g., age, gender, education level), medical conditions, medications, driving-related body structure and functions (e.g., visual, psychomotor, and cognitive), driving skills and capacity, and knowledge of traffic rules. These personal factors are gathered by clinicians during the pre-road evaluation to build a holistic view of the driver and inform the on-road component of the evaluation.

The SODE and the NDO consider different aspects of personal factors, leading to two different interpretations of driving performance. The SODE is designed to assess a driver's driving capacity, such as manipulating the vehicle, anticipating potential hazards and reacting to sudden traffic changes based on skill and knowledge. For older adults who are highly experienced drivers with sufficient skills, the results of the SODE are usually explained by changes or impairments in the driving capacity, such as decreased divided visual attention ability or slower psychomotor processing speed.

On the other hand, the NDO approach not only evaluates driving skill, knowledge, and capacity, but also examines the driver's perception of driving, including personal internal beliefs and motivation, self-awareness of driving capacity, driving confidence and comfort, and self-efficacy of driving. These personal factors impact a driver's strategic decisions about when and where a drive is purposeful, meaningful, perceived as functionally appropriate, and how the driving task is done. For example, an older adult who identifies himself as the main driver in a family will be encouraged to maintain driving in his daily routines, whereas being aware of declining visual function could trigger spontaneous restrictions from driving at night. In other words, a driver's self-perception of driving tilts the balance between a driver's driving capacity and the support and demands in the chosen environment (Lindstrom-Forneri et al., 2010). For clinicians, clinical concerns are raised when older drivers' self-perception of driving has negative impacts on driving competence, especially for those who commonly drive into environments where the context demands exceed their declining driving capacity. Although many studies have found that older drivers tend to avoid the driving situations in which they don't feel confident (Marottoli et al., 1998; Myers et al., 2008), and that decreased driving frequency and mileage (Donorfio et al., 2008), female gender (Molnar et al., 2014), poorer self-rated health (Kostyniuk et al., 2008), and having other friends or family members to provide rides (Molnar et al., 2014) are associated with modified driving behaviors, there is still a lack of empirical measures to verify the match between a driver's capacity and the decisions they make in their everyday driving. The NDO is a potential client-centred approach to present a driver's competence in their familiar, meaningful, and purposeful context.

The design of the two on-road driving evaluation approaches may cause a client to react differently, namely due to the level of stress and anxiety generated. During a SODE, the stress related to the unfamiliar testing context could lead to a high level of anxiety. Past research found that drivers with less confidence have a higher level of anxiety, which is related to more driving errors and failures in a SODE (Fairclough et al., 2006). It is not clear whether poor driving capacity produces a low level of confidence or whether low confidence level and high test anxiety exacerbate the performance of an older driver with poorer capacity. Also, older drivers with

Alzheimer's Disease or mild cognitive impairment are more likely to exhibit this negative relationship during a SODE, compared to healthy older drivers (Bhalla et al., 2007). In contrast, the NDO occurs in an environment in which the driver is very familiar. With high familiarity with the environment and minimum interference from observation, the driver is assumed to have less anxiety to negatively influence an older driver's performance. For a clinician administering each of these driving evaluation approaches, the effect of stress on an older driver's performance should be carefully monitored and accurately interpreted.

3.3.4 Detecting Change Over Time

Tracking an older driver's change in driving capacity over time is common practice in clinical settings. As clients may have had some functional impairments impacting their driving capacity at the initial intake, those who continue to drive would need to undergo a follow-up evaluation for monitoring the progress of their medical condition and its impact on driving ability.

Each of the two approaches detects an older driver's change in different ways. Clinicians should choose the appropriate approach to monitor an older driver's performance over time and correctly interpret the results. For the SODE, where the driving tasks and environmental components are fixed, the variation in an older driver's performance over time would be largely explained by the change in the driver's driving capacity. In contrast, using the NDO, the older adult's driving capacity is not the only influential factor. By properly modifying the task and environmental components, a driver, who's driving capacity may have been declining, could still demonstrate good driving performance during subsequent NDOs. In other words, the interpretation of the change in driving performance over NDO sessions should take all components (personal, occupational and environmental) into consideration.

To better illustrate this idea, a case example is presented using the PEO model. A client with mild cognitive impairment takes two on-road driving evaluations using one of the approaches to monitor the change in his driving performance. By comparing the results between the SODE sessions, the therapist may find that his performance is deteriorating and interprets that the declining cognitive functioning has been gradually impacting his driving performance. Since the occupation and environmental components are relatively stable in this approach, the poorer driving performance at follow-up is likely to be caused by the outward movement of personal components, leading to a poorer person-occupation and person-environment fit (figure 3.2a to 3.2b). On the other hand, when using the NDO to track the change in driving performance, the results would depend on the client's self-perceived driving ability and needs. Older drivers with mild cognitive impairment often voluntary modify their driving to decrease the environmental and occupational demands and compensate for their declining function (O'Connor et al., 2013). In this case, the client's driving performance could remain satisfactory in his milieu at the follow-up observation sessions due to the improved fit of person-occupation and person-environment interactions, even if the driving capacity may have been declined (figure 3.2c).

3.4 Discussion

The purpose of this article was to compare and contrast two on-road driving evaluation approaches, namely, the SODE and the NDO. Using the PEO model, which focuses on the interrelationship between an occupation (driving), the person (driver), and the environment, the differences between these two approaches as well as the clinical utility of the evaluations are discussed. For occupation, the SODE requires a client to drive on certain routes by following signs and instructions to demonstrate their tactical and operational driving skills, while during a NDO, the entire driving context and task is highly self-determined to show the driver's situational judgement at the strategic and tactical levels, as well as their performance at the operational level. The environment of a SODE is designed to cover a broad range of road types and complexities, and the driver is usually unfamiliar with the designated driving area and car used during the evaluation. During a NDO, the driver is highly familiar with his or her own car and the area around home, and the environment complexity varies according to the driver's own judgement. The SODE focuses on the driver's driving capacity, skill, and knowledge, and the driving context is likely to create a high level of stress level for older drivers. In contrast, the NDO not only assesses a driver's driving capacity, but also factors in the driver's self-perception and judgment. As the drive takes place in the driver's everyday driving condition with minimum interference, it is assumed that the observation is less stressful for the client. Longitudinally, the SODE is able to detect the change of a driver's driving capacity over time, while the NDO indicates the driver's overall driving performance in the ecological, self-chosen environment of each observation.

These differences in each of the PEO components indicate that two approaches provide different ways of describing a client's driving performance. The SODE examines a driver's capacity and deficits in a controlled environment, assessing "what a person with a health condition can do in a standard environment" (World Health Organization [WHO], 2002). On the contrary, the NDO corresponds to the client-centred point of view, and focuses on driving performance, or "what they actually do in their usual environment" (WHO 2002). While administering this evaluation, therapists "observe the quality of the transaction between the client and the environment as the client performs a task that is familiar, meaningful, purposeful, and relevant" (Fisher 1998) (p. 517). In other word, a client's performance in the NDO needs to be explained by a comprehensive consideration of the interaction between personal, occupational, and environmental components.

Clinicians should select an appropriate driving evaluation approach based on the purpose of the evaluation. One way to determine which approach should be used is to examine the older driver's occupational profile, especially their self-perception of driving. If an older driver has the motivation to drive in any area and time without restraint, the SODE which tends to examine one's driving capacity in challenging driving conditions and tasks is recommended. On the contrary, for an older driver who is aware of the changes in their driving capacity and challenges in their driving environment, and is willing to modify their driving environment and tasks, the NDO might be the better choice to verify the driver's actual performance in their everyday driving environment. Using this approach, the driver has less chance of losing driving privileges, and it may be more suitable for making recommendations for a restricted or conditional license, which provides limitations to a driver's geographic area and driving conditions, such as driving only near home, not on highways or at night (Marshall et al., 2002).

Understanding the strengths and limitations in terms of the psychometric properties and clinical use of each driving evaluation approach can also shed lights on selecting the proper evaluation tool. The SODE is a solid evaluation approach that has been developed for years and is now widely accepted as a gold standard to assess a driver's ability. Similar evaluation context, format, and targeted maneuvers and behavioral items have been recommended in several national/international guidelines. The expanded sections of the SODE (i.e., self-directed driving) give extra information about the driver's capacity. The limitation of this approach is the lack of ecological validity. The evaluation context is likely to create additional challenges (i.e., test anxiety due to unfamiliar environment) to a driver and their driving performance during this evaluation may not represent their performance in their everyday driving context.

The NDO, in contrast, is a relatively novel approach for clinicians. This approach has strong ecological validity which shows an older driver's everyday driving context and performance in a natural, unobtrusive manner. A therapist could provide feedback to the driver after the observation by reviewing the recorded video clips. The video clips of the at-risk scenes would be helpful for the therapist to start a discussion with the client and collaborate on developing transportation-related treatment goals and plans. Nevertheless, this approach requires improvements and refinements to the evaluation format, recording forms, and technology applications. Unlike the SODE, which has a route that takes around 45-60 minutes, the appropriate sampling duration of a NDO has not yet been defined. The observation duration should be long enough for the driver to become familiar with and neglect the recording devices and to provide sufficient data to represent a driver's everyday driving, but short enough to be feasible for clinical use. One NDO protocol, the electronic Driving Observation Schedule, has proposed a duration of observation of approximately 25 to 30 minutes (Vlahodimitrakou et al., 2013). This protocol is able to capture an older driver's typical driving route types, and drivers are reporting that they are at ease with being observed (see Appendix 2). In addition, most studies using the NDO approach have only analyzed the driver's behavior. Adopting a systematic, objective, and feasible recording form that accounts for physical environmental components and secondary tasks would improve the content validity of the NDO. For example, developing a scale to measure the complexity and familiarity in which a client drives or examining the effectiveness of new vehicle technologies for guiding an older driver to reach a destination. These additional pieces of information may also be beneficial for clinicians to analyze the underlying problems of an older driver's competence. Furthermore, there are still some challenges about how to teach therapists to install the in-car recording devices, and synchronize and manage the electronic data. A learning package that could deal with these hardware and software issues may be required. Although, the NDO still requires further developments before it can be included in clinical practice, it nonetheless represents a promising tool that could offer clinicians a different perspective on driving performance compared to the SODE.

3.5 Conclusion

The SODE and the NDO assess older drivers' on-road driving performance with different task demands in varying environments. This article compared the impact of occupational, personal, and environmental components between these two approaches for the evaluation of an older driver's performance, as well as how these components change over time. Based on this knowledge, clinicians should be able to articulate the strengths and weaknesses of the two evaluation approaches and choose an optimal way to evaluate an older driver's performance.

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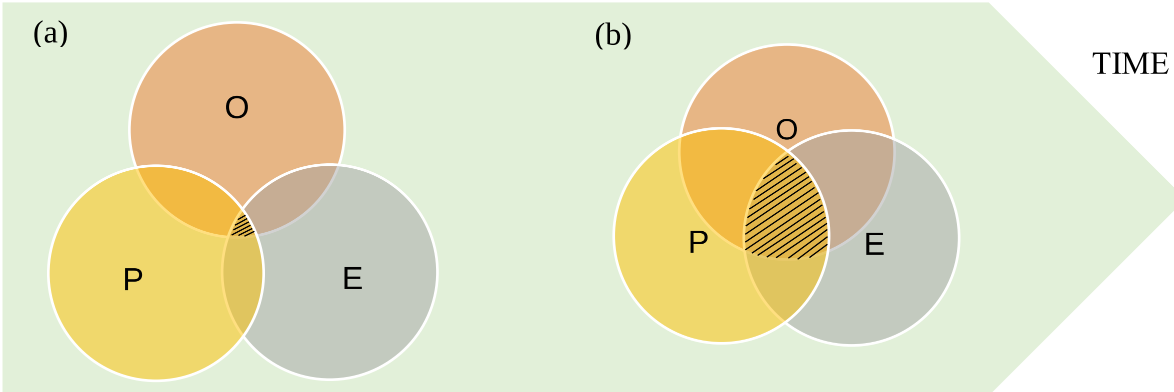

Figure 3.1: An illustration of the progress of one's performance using the Person-environment-occupation (PEO) model. E: Environment; O: Occupation; P: Person. This example shows that one's performance (shadowed area) is improved over time due to a greater person-occupation-environment fit.

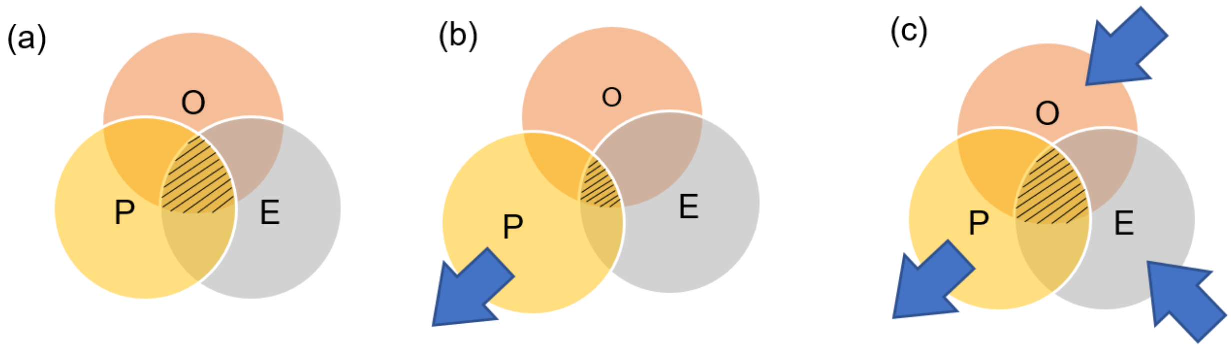

Figure 3.2: Detecting change in driving ability over time using different on-road driving evaluation approaches. E: Environment; O: Occupation; P: Person. (a) The person-occupation-environment fit at the initial evaluation. (b) using the SODE, the change in driving performance is largely explained by the change in the older driver's capacity under the fixed occupation and environment demands (arrow: declining driving capacity leads to less person-occupation and person-environment fit). (c) using the NDO, the driving performance is the outcome of the interaction between the driver's person-occupation-environment components (arrows: proper modifications in occupation and environment components regarding the declining driving capacity).

CHAPTER 4

Development of a weighted scoring system for the eDOS

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4.1 Preface

The first manuscript compared the differences between the standard on-road driving evaluation (SODE) and the naturalistic driving observation (NDO) using the person-occupational-environment model. The results highlighted how older adults' driving performance might differ using the two approaches. The strengths and weaknesses of each approach were identified to help clinicians choose the optimal way to evaluate an older drivers' performance.

One challenge of the NDO approach is that the recording of environmental complexity is often overlooked. While some drivers may drive on routes with more traffic or higher speed limits, such as highways or boulevards, others may only drive on quiet streets or straight service roads to reach their everyday destinations. Without considering the differences in the environmental complexity, the comparison of driving performance between clients or across observation sessions would be problematic.

In this thesis, the NDO was measured using a novel approach, the electronic Driving Observation Schedule (eDOS). The original eDOS total score was calculated by the percentage of appropriate maneuvers over the total number of maneuvers. This formula did not take into consideration that driving errors could have different levels of risk. Some errors are more serious than others, depending on the type, driving maneuver, and the environmental complexity in which it occurs.

To better describe the complexity of the maneuver/environment during each eDOS observation and to better represent older drivers' performance using driving error recordings, a study was needed to create weighted scores to systematically quantify the complexity of maneuver/environment and to give weights to each error according to its risk level.

This chapter focuses on how these weighted eDOS scores were created.

4.2 Abstract

The electronic Driving Observation Schedule (eDOS) is a novel approach to assessing older drivers' performance in their everyday driving environment. The original eDOS total score neither demonstrates differences in driving environment complexity during each eDOS observation, nor accounts for distinct risk levels of different driving errors made in each driving environment complexity. This study was conducted to generate one score to represent the complexity of the driving route during each eDOS observation and one weighted eDOS total score to represent older drivers' performance accounting for the severity of driving errors and complexity of maneuvers in their corresponding environments. A literature review, a two-round survey with 13 experts in driving rehabilitation, and iterative discussions between primary investigators were conducted for generating the two scores. Two formulae were created to calculate a weighted maneuver/environmental complexity score and a weighted eDOS total score. Limitations of the scores and future research directions are discussed.

Keywords: Automobile driving, naturalistic driving observation, weighted score, assessment

4.3 Introduction

The naturalistic driving observation (NDO) is a novel approach to assessing older adults' driving performance with minimum interference in their everyday driving environment. Unlike the standard on-road driving evaluation (SODE), which requires older adults to drive an unfamiliar vehicle on predetermined routes guided by a driving instructor, results generated from the NDO is considered to represent older drivers' everyday driving performance (Chen, Gélinas, & Mazer, 2018).

Nevertheless, scoring systems used in the NDO do not adequately capture the driving performance of older drivers and need to be improved. One challenge comes from the large variation of driving environments and routes involved in each NDO drive. During the NDO, clients are asked to select their own route within their own living area (e.g. rural, suburban, and urban). The complexity of the driving environment differs between clients and across each NDO session. Some drivers might select more challenging routes, including highway and left turns at busy boulevards, while others may only drive in simpler environments, such as quiet residential areas and straight roads. Without a system to weight the complexity of the various driving environments, driving performance cannot be compared between individuals or between sessions (e.g. to monitor changes in driving performance over time).

Another challenge is related to the rating of driving errors as a method of representing one's driving performance. All driving errors made during a NDO should not be given the same weight. For example, a rolling stop is an error type that is less risky than the lack of sufficient observation of road environment at intersections (Dobbs, Heller, & Schopflocher, 1998); and no signaling at lane changes on a busy boulevard would be more dangerous than the same error made on a quiet street. Di Stefano and Macdonald (2006) stated that "scoring systems should give the greatest weight to errors that, considering the road traffic context, are clearly hazardous because these are the strongest discriminators of impairment level and risk" (pp. 271). Having a weighted score that accounts for the risk level of different types of driving errors and the complexity where they occurred is necessary to better represent drivers' performance in their everyday driving environment.

The idea of weighting driving errors for a driving evaluation is not new. Several SODE protocols have created different systems to give weights based on the severity of errors and the intervention of driving instructors. For example, Classen et al. (2017) rated drivers' performance at each maneuver using a 5-point Likert scale (0=no errors, 1=makes one or more non-critical errors, 2=makes one or more critical errors, 3=requires verbal cues or minor physical intervention, 4=requires critical physical intervention). Using similar definitions, other approaches have adopted a dichotomous scale (Odenheimer et al., 1994), a 3-point Likert scale (Richardson & Marottoli, 2003), a 4-point Likert scale (Justiss, Mann, Stav, & Velozo, 2006; Shechtman, Awadzi, Classen, Lanford, & Joo, 2010; Vaucher et al., 2015), or a mixed scale (i.e., some maneuvers use a 2-point scale, while others are rated by a 3-point scale) (Hunt et al., 1997). Although the physical intervention from driving instructors is closely associated with the result of failing SODEs (Di Stefano & Macdonald, 2003; Hunt et al., 1997; Janke & Eberhard, 1998), during the NDO, there are no driving instructors, and observers avoid interfering with the driver. Therefore, the severity of errors defined by the verbal or physical intervention of the instructor is not applicable to the NDO.

Other studies developed weighting systems that do not consider the intervention of driving instructors (Baldock, Mathias, McLean, & Berndt, 2006; Dobbs et al., 1998; Janke & Eberhard, 1998; Kay, Bundy, Clemson, & Jolly, 2008). These weighting systems separate driving errors into habitual errors (or "high-frequency low-severity errors"), hazardous errors (or "low-frequency high-severity errors"), and critical errors. Lower weightings are given to habitual errors to address the large number of errors committed frequently by experienced drivers, that do not necessarily compromise driving safety. For example, lack of mirror check and not signaling are considered to be habitual errors in one SODE study while they account for 41% of total errors (Berndt, May, & Darzins, 2015). Rolling stops and speed errors (i.e., not properly adjusting speed when the speed zone changed) are the other two habitual errors commonly seen among experienced drivers, but they do not discriminate between healthy and cognitively impaired drivers (Dobbs et al., 1998). Greater weighting is assigned to hazardous errors that compromise safety in certain driving conditions, such as a lane positioning error that may obstruct upcoming vehicles. Substantial weights are usually given to critical errors that led to failing a client in a driving evaluation, because these errors are defined as "a control action by a driver that results in a crash, near crash, or a high-risk encounter (without an adverse outcome)" (pp.7, Transportation Research Board Sub-Committee ANB 60, 2016). The actual weights given to each type of errors differed in these weighting systems. Construct validity, discriminative validity, criterion validity or Rasch analysis were used to validate the effectiveness of these weighting systems on discriminating at-risk older drivers. Details of these weighting scales are provided in Table 4.1.

These studies highlight the differences in the severity of driving errors and the related scoring weights for SODEs. An individual weighting system is also necessary for NDO protocols such as the one applied in this study, the electronic Driving Observation Schedule (eDOS). The eDOS was developed for the Candrive/Ozcandrive study, an international longitudinal cohort study on driving in seniors, to systematically observe and record older drivers' driving behavior in their everyday driving environment, as well as to monitor their changes in driving performance over time (Koppel et al., 2013; Koppel et al., 2016; Vlahodimitrakou et al., 2013). When using the eDOS scoring procedure, driving behaviors and the environment at each maneuver are systematically recorded on a tablet. Clients' driving environment is recorded in terms of maneuvers (i.e. intersection negotiation, lane-changing, merging, maneuver-free driving or low speed maneuvers) and corresponding environmental descriptors (i.e. number of lanes, speed limit, and traffic volume). Within the category of intersection negotiation, 13 types of intersections were defined by the combination of traffic control signage (i.e. traffic light-with arrow or flashing light, traffic light-no arrow, yield or stop sign, roundabout, and no traffic sign) and driving directions (i.e. straight through, left and right turn). For each of the environmental descriptor, one of three levels could be chosen: one to three lanes (more than three lanes would be recorded as three); speed zone at low (< 50 km/h), medium (50-70 km/h), and high (80-100 km/h); traffic volume at low, medium, or high. These variables are used to describe the level of complexity of an older driver's route choice during each eDOS observation.

Also, driving errors committed at each maneuver are coded as appropriate or inappropriate in six main categories: observation of road environment (no mirror use or no head checking); signalling; speed regulation (too fast or too slow); gap acceptance (missed opportunity, unsafe gap, or failure to yield); road rule compliance (non-compliance with traffic signage or crossing pavement); vehicle or lane position (lane drifting, hitting curb, or inappropriate following distance). In addition, critical driving errors are noted when the participant is involved in a crash or near-crash. Operational definitions of all these factors are provided in a detailed eDOS administration manual (Candrive Research Team, 2017).

By identifying the error type and the corresponding environmental complexity where errors are recorded, it is possible to systematically differentiate between the habitual, hazardous, and critical errors that occur during the eDOS observations, similar to the weighting systems developed in the past studies on SODEs. Since the original eDOS total score was generated only by the proportion of appropriate maneuvers over the total number of maneuvers recorded, without accounting for the different levels of severity of error types (except the score for a critical error was doubled in the formula) nor the environmental complexity where the errors were observed (see Appendix 3), the risk level of an older adult's driving performance in their naturalistic driving environment could not be accurately estimated. Therefore, the first objective of this study was to generate a score to represent the complexity of the driving route chosen by the client at each eDOS observation. The second objective was to develop a scoring and weighting scale for the eDOS total score accounting for the severity of driving errors and complexity of maneuvers in their corresponding environments.

4.4 Methods

A two-round electronic survey with experts in driving rehabilitation was administered. The first round aimed to design a driving maneuver/environmental complexity classification system for the eDOS. The results would be used to generate a score for the complexity of each type of driving maneuver/environment recorded on the eDOS. The second round focused on gathering feedback for refining the classification system and determining a weighting system for the eDOS score accounting for the type of driving errors and their corresponding driving maneuvers/environments complexity.

4.4.1 Participants

Participants were recruited using a convenience sampling method from our group of collaborators, including the clinical sites of the Centre for Interdisciplinary Research in Rehabilitation of Greater Montreal (CRIR) and partnering sites (Centre de Réadaptation Constance-Lethbridge and L'Institute de Réadaptation en déficience physique de Québec), as well as two research groups in driving (OzCandrive/Candrive and I-CHAT). The inclusion criteria were:

a) clinicians (i.e., trained occupational therapists in driving evaluations) and driving instructors who have more than two years of experience in on-road driving evaluation among older drivers or b) researchers who have expertise in the on-road driving evaluation.

4.4.2 Procedure

Before the first round of survey, primary investigators (i.e., IG, BM, and YTC) integrated the driving maneuvers and environmental variables from the eDOS into 14 categories. This was done based on the experts' opinion and the literature review of previous weighting systems. This step scaled down the number of combinations of maneuver (i.e. 13 intersection types, 2 types of lane changes, and merging) and environment descriptors (i.e. 3 levels of 3 environmental descriptors) to ensure that completing the survey would be feasible for participants. Detailed definitions of the driving environments are presented in Appendix 3.

The survey was built on Limesurvey, a free on-line platform supported by McGill University. A pilot test was completed by one clinician and one researcher. Based on their feedback, modifications of wording and questionnaire format were done before the survey was sent to the eligible participants. Participants who received an invitation email indicated their consent to participate on the first page of the first round of the survey (see Appendix 3). Participants were given one week to complete the first-round of the survey; one reminder email was sent if the survey was not returned within a week. If the participant did not reply to the email or respond to the survey by the next week, they were considered to have refused to participate in the study.

Once the data collection was complete, the primary investigators examined the results to determine the classification system for the complexity of driving routes. These results were used to prepare the second round of survey, which was only sent to the participants who completed all the questions for the first round.

After the data collection and analysis of the round-two survey was completed, the classification system of driving maneuver/environment was modified and methods to calculate the weighted eDOS score and the weighted driving maneuver/environment complexity score were determined by the primary investigators. A report of the survey results was sent to other experts who had knowledge and experiences using the eDOS (i.e. BV, SK, and JC). Their comments and opinions on this document were used to refine the final calculation of the two scores.

Ethical review of this study was approved at the CRIR and Centre Intégré Universitaire de Santé et de Services Sociaux.

4.4.3 Round-one survey contents and analysis

The first-round of the survey consisted of four parts: a consent form, rating and ranking the complexity of the fourteen maneuver/environmental conditions, and demographic information. After consenting to participate in the study, participants were asked to rate the difficulty of the fourteen maneuvers in different driving environments on a scale from 1 to 10 (1 = least difficult and 10 = the most difficult). They were then asked to rank the fourteen maneuver/environment categories from the least difficult to the most difficult. Finally, they completed questions about their demographic information, including their age, gender, years of experience in driving evaluation.

The primary investigators conducted the descriptive analysis to examine the centrality and dispersion of the ratings; mean, median, standard deviation, and range. According to the participants' ranking of the environment complexity, the fourteen categories were regrouped to represent similar levels of difficulty in order to create a simpler driving maneuver/environmental complexity classification system. Participants' demographic information was analyzed using descriptive analysis.

4.4.4 Round-two survey contents and analysis

The second-round survey comprised two parts. The first part asked participants to examine the round one survey results for the driving maneuver/environment complexity classification system. For each category, they were asked to rate the level of agreement for the categorization on a) the conditions that were grouped together and b) the relative difficulty level compared to the previous and following category using a 5-point Likert scale (1= strongly disagree to 5= strongly agree). At the end of this survey, participants were asked to type their comments, opinions, and thoughts about the classification system. Answers from this part of the round-two survey was used to refine the classification system.

Participants were then asked to rate the level of risk for each possible error in each of the seven categories of driving maneuver/environments using a 3-point Likert scale (1 = low risk, 2 = moderate risk, and 3 = high risk). Low risk errors correspond to habitual errors that do not compromise safety and are common amongst experienced drivers; moderate risk errors are related to raised safety risk; and high-risk errors are driving errors that may result in a crash or near-crash, similar to a “critical error”.

Descriptive analyses were conducted to examine the centrality and dispersion of the ratings. Using the results, the primary investigators determined the risk level for each error at the corresponding maneuver/environment complexity category. A formula of weighted eDOS scores was generated by adding up the weights of each error made by a client during each eDOS observation.

4.4.5 Sample size estimation

Past studies reported that for a homogeneous group of experts who have similar training and knowledge, a sample of 10 is appropriate for surveys (Akins, Tolson, & Cole, 2005; Delbecq, Ven de Ven, & Gustafson, 1975).

4.5 Results

4.5.1 Round-one survey results

In this round, 27 experts in driving rehabilitation were invited and 13 of them completed the survey (response rate = 48.1%). The majority of participants were based in Canada (n = 9), while the others were located in Australia (n = 2), Israel (n = 1), and Sweden (n =1). Their mean age (SD) was 49.3 (SD=9.7) years, including 10 females (77%). On average, participants had 15.9 (SD=11.0) years of experience working in driver rehabilitation.

Results of the rating and ranking of the fourteen categories of driving maneuver/environmental complexity are presented in Table 4.2. The primary investigators examined the results together and drafted an initial driving maneuver/environment complexity classification system based on the median of the ratings and rankings. Scenarios (i.e., maneuvers in different driving environment) with similar complexity level were combined into the same category and seven hierarchical categories from simplest (Category 1) to most complex (Category 7), were created (Table 4.3).

4.5.2 Round-two survey results

Invitations emails were sent to the 13 participants who complete the first-round survey, and 10 participants replied to the second-round survey (response rate=77%).

The mean (SD) agreement for the categorization of conditions that were grouped together (i.e. category 1, 3, 5, and 7) was 3.9 (SD=0.7). For the relative difficulty level in each category, the mean was 3.7 (SD = 0.4) for the seven categories. Added comments included the following: a) parking and lane change were two maneuvers difficult to be compared with the other maneuvers. These two maneuvers need certain driving skill, but their difficulty level varies with the type of parking (e.g., parallel, angle parking), time pressure and traffic volume in which they take place, which were not clearly identified in the definitions; b) the combination of the maneuvers in category 5 should be reconsidered because the difficulty level of driving on highway/high-speed zone and “Right turn at an intersection with a nondirectional light or sign on major roads” would not be considered as being similar in level of complexity; c) general rules for the participants to compare the relative difficulty levels were “residential areas should be easier than major roads” and “straight driving on streets is easier than any types of turns on a similar road”.

Based on the ratings for the complexity of the driving maneuver/environment classification system created based on the round-one survey, comments from the survey participants, and the feedback from the eDOS experts, the primary investigators adjusted the items included in each category and created the final version of the classification system (Table 4.4). This classification system contains five categories ranging from Category A (the least difficult driving scenarios) to Category F (the most difficult driving scenarios). “Category B” which included low speed maneuvers (i.e. parking, pulling into curb, and reversing) was excluded from the classification system in response to the feedback from the round-two survey.

For the second part of round 2 survey, the risk level of the 13 types of driving errors made in each scenario was determined by the median of participants' rating. In general, errors made in simpler scenarios have lower risk level compared to the same type of error made in more complex driving scenarios. No looking, unsafe gap, failure to yield, and non-compliance to road sign were four error types that had higher risk levels. The "no looking" error was rated as a high-risk error in all kinds of driving scenarios. The other three error types had moderate risk even in the simplest driving scenario (i.e. the category A) and were rated as high-risk errors in other driving scenarios (i.e. category C to category F). In addition, all of the errors made in the most complex driving scenario (i.e. category F) were rated at the high-risk level. Details of the risk level for each error type in each driving scenario are presented at Table 4.5.

4.5.3 Creating the driving maneuver/environment complexity score

To represent the difficulty level of drivers' overall route during the eDOS observation, the weighting for each category was determined by the primary investigators. The denominator represents the total number of maneuvers in each eDOS drive; this provides a mechanism to control for varying number of maneuvers between drives. A weighted maneuver/environmental complexity score is calculated by:

(1 * Category A + 1.5 * Category C + 2 * Category D + 2.5 * Category E + 3 * Category F) /
Sum of the number of intersections, lane changes, and merging

The maneuver/environmental complexity score ranges from 1 to 3; higher scores indicate more difficult, complex driving maneuvers and environments.

4.5.4 Creating the weighted eDOS total score

The weighted eDOS total score represents a driver's driving performance in their everyday driving environment. This score was generated by summing the weighted driving errors, which were based on the error type and risk level in corresponding maneuver/environments (1=low risk, 2=moderate risk, 3=high risk) (Table 4.5). A lower weighted eDOS total score indicates better driving performance, while higher scores imply that the driver either committed some severe errors (e.g. choosing an unsafe gap during a lane change on a boulevard) or demonstrated several bad driving habits (e.g. no signalling on quiet residential streets for a right turn).

4.6 Discussion

To our knowledge, this study is the first to create a classification system for the complexity of driving maneuvers and environments for a NDO protocol to represent the overall difficulty level of the driving route taken during an eDOS driving observation. In addition, the weighted eDOS total score was created to account for the number and risk level of different types of driving errors occurring at corresponding maneuver/environments. Compared to the original formula of the eDOS total score, which calculates the proportion of appropriate driving maneuvers during the whole drive, this weighted score will better represent the potential driving risk when driving on familiar routes.

The two scores were developed based on a literature review, a two-round on-line survey with experts in the field of driving rehabilitation, and opinions from researchers who designed and administered the eDOS. In consistent with past studies, it was found that some driving environments and types of driving errors are more complex and riskier than the others. For example, around 50% of critical errors during a SODE was found to be occurred at lane changing, merging, and turning at a busy intersection (Di Stefano & Macdonald, 2003; Dobbs et al., 1998). In our study, lane change and merge were categorized in more complex driving conditions (category D to F), and intersections with uncontrolled left turn was one of the most challenging condition for older drivers (category F). In addition, Kay et al. (2008) reported that drivers who select an unsafe gap, do not fully observe their surroundings, or drive in an inappropriate position are some of the common situation that necessitates driving instructors to take control of their vehicle. Results from our survey is in line with this finding, as lack of driving environment observation, choosing an unsafe gap, failure to yield, and non-compliance to road sign are the errors rated with higher risk levels than the other types of errors. The weightings in both scores were determined by the primary investigators and agreed upon by experts in the eDOS.

However, one limitation of the weightings is that these scores are rated on ordinal scales, rather than on ratio scales. That is, these weightings provide a general ranking of the categories in the driving complexity classification system and the risk level of driving errors in different driving complexity categories, but the "distance" between the categories or levels is not assumed to be the same (Portney & Watkins, 2009). For example, in the weighted eDOS score, the low-, moderate-, and high-risk errors were assigned a weight from one to three, respectively; however, the risk level of committing three low-risk errors cannot be assumed to be equal to committing one high-risk error. As a result, weightings in the two scores could reflect the relative driving route complexity and risk level to a certain extent and allow for comparisons across clients and eDOS sessions, but the scores may not be absolutely accurate. Weighted rating scales in previous studies gave one point for a habitual error, 2, 5, or 11 points for a hazardous error, and 5, 10, or 51 points for a critical error (Baldock et al., 2006; Dobbs et al., 1998; Janke & Eberhard, 1998; Kay et al., 2008). Due to the range of weights for the weighted eDOS score (1-3), the eDOS may have less power to discriminate between low and high-risk older drivers. Future studies will be needed to explore and validate the weighting scales for the eDOS scores.

4.7 Conclusion

The eDOS is a NDO used to observe and record drivers' naturalistic driving performance in their everyday driving environment. This study was conducted to create a driving maneuver/environment complexity score to represent the complexity of the maneuver and environment during the eDOS drive, as well as to create a weighted eDOS score that accounts for the error types within a corresponding driving environment. Compared to the original eDOS total score, the weighted eDOS score could better represent older adults' driving risk observed. Also, the driving maneuver/environment complexity score can be used to compare differences in the complexity of drivers' route choice across clients and across eDOS sessions. Future research is needed to validate the two weighted scores for discriminating at-risk drivers.

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Table 4.1: A summary of driving error weighting systems

Authors (Year)	Location	N	Participants' mean age (SD and/or range)	Development of weighting	Weighting*	Weighting validation	Note
Dobbs, Heller, & Schophlocher (1998)	Alberta CAN	155	Clients with referrals (mostly MCI or AD), 72.7 (9.1)	Expert judgments	51* critical errors 5* or 11* on 12 categories of hazardous errors (p.367 for error def., how specific weightings given on each category after experts' adjustments are not reported) Cut-off score = 50	**Known-group:** Using modified sum of weighting score to identify failed clients in each group **Criterion**: Score of five error categories account for 57% of variances in global rating	Rolling stop and speed errors are frequent errors, but do not differ the three groups
		30	Volunteers aged 30-40, 35.6 (3.2)				
		68	Volunteers aged 65 years and over, 69.4 (6.8)				
Janke & Eberhard (1998)	California USA	75	Clients with referrals, 75.7 (60-91)	Not justified	Unweighted: total number of errors	**Construct**: the correlation with age and off-road evaluations (i.e., reaction time, cognitive and visual functioning tests)	The reliability of this evaluation is moderate (0.51-0.60 on total errors)
		31	Volunteers, 68.4 (56-85)		Weighted: sum of 3* hazardous errors 5* critical errors (def. are not clear, reported by examples)		
Baldock, Mathias, McLean, & Berndt (2006)	Adelaide AUS	104	Aged 60 years or more, 74.2 (6.3, 60-92)	Literature review and empirical test (best weighting to predict the pass/fail results)	10* critical errors 5* hazardous errors 1* habitual errors (p. 1040 for error def.) Weighted score mean (SD, range) = 117.6 (78.3, 18-443)	**Criterion**: 79% sensitivity and 97% specificity	Cut-off score was not reported
Kay, Bundy, Clemson, & Jolly (2008)	Sydney AUS	80	Healthy volunteers, 69 (6.3, 60-86)	Empirical test by Rasch separation statistic > 2 as satisfactory†	5* critical errors 2* hazardous errors 1* habitual errors (p. 758 for error def.) Cut-off raw score=40, scaled score=-54.0 for 81% sensitivity and 95% specificity‡	**Rasch**: "(the weighting) yielded the best psychometric properties" (absolute number of the separate statistic using this weighting system was not reported)	Examined Baldock et al. (2006) method, separation index = 1.14
		20	Volunteers with visual impairments aged 60 and over, 72 (6.8)				

*Critical errors are defined as the physical intervention (apply the brake or take control of the steering wheel) by the driving instructor or a control action by a driver that results in a crash, a near crash, or a high-risk encounter (without an adverse outcome); hazardous errors are defined slightly differently in each study, but mainly indicate the general error types (Different definitions in Dobbs et al., 1998; Janke and Eberhard, 1998, but adjusted for the unity of terminologies)

†Separation statistic: provides evidence of internal reliability or the ability of the instrument to separate groups of participants into levels of ability

‡The negative scaled score is due to the errors; not correct behaviors

Table 4.2: Descriptive analysis of rankings and ratings of each driving maneuver/environmental complexity (n=13)

Code	Item	Ranking*				Rating*			
		Mean	Median	SD	Range	Mean	Median	SD	Range
1	Highway or high-speed driving	8.3	8	3.6	2-14	6.3	6	2.1	2-10
2	Drive straight through at an intersection with directional lights on major roads	5.2	6	2.8	1-10	4.0	4	2.1	1-8
3	Left / right turn at an intersection with directional lights on major roads	7.2	7	3.0	3-12	4.9	4	1.6	3-8
4	Left turn at an intersection with a nondirectional light or sign on major roads	12.1	12	2.0	7-14	8.9	9	1.1	7-10
5	Right turn at an intersection with a nondirectional light or sign on major roads	8.9	9	1.8	6-13	5.9	6	1.4	4-9
6	Drive straight through with a nondirectional light or sign on major roads	7.8	9	3.8	2-13	5.5	6	2.1	3-9
7	Drive in and out of a roundabout on major roads	11.2	11	2.2	8-14	7.9	8	1.4	6-10
8	Left turn at an intersection with a nondirectional light or sign on quiet residential streets	6.9	6	3.5	3-14	5.3	5	1.8	3-10
9	Right turn at an intersection with a nondirectional light or sign on quiet residential streets	4.3	3	3.3	2-12	3.6	3	1.1	2-6
10	Drive straight through with a nondirectional light or sign on quiet residential streets	3.2	3	2.7	1-11	2.9	3	1.9	1-7

11	Drive in and out of a roundabout on quiet residential streets	3.6	4	2.1	1-7	3.2	4	1.7	1-6
12	Lane change	9.4	10	2.4	5-13	6.6	7	1.3	4-8
13	Merging onto highway	12.0	13	2.7	4-14	7.9	8	1.6	6-10
14	Parking	4.8	5	3.9	1-14	4.3	5	2.7	1-10

*In both ranking (range 1-14) and rating (range 1-10) scales, higher number indicates greater difficulty

Table 4.3: Round one survey results for the driving maneuver/environment complexity classification system

Category 1	Drive straight through with a nondirectional intersection on residential street
	Enter and exit roundabout on residential street
	Right turn at nondirectional intersection on residential street
Category 2	Parking
Category 3	Drive straight through directional intersection on major road
	Left / right turn at directional intersection on major road
Category 4	Left turn at nondirectional intersection or sign on quiet residential street
Category 5	Drive straight through with a nondirectional intersection on major road
	Right turn at nondirectional intersection on major road
	Highway or high-speed driving
Category 6	Lane Change
Category 7	Enter and exit roundabout on major road
	Merging onto major road or highway
	Left turn across traffic at nondirectional intersection on major road

Table 4.4: Final version of the driving maneuver/environment complexity classification system

Category A	Drive straight through a nondirectional intersection on residential street
	Enter and exit roundabout on residential street
	Right turn at nondirectional intersection on residential street
	Drive straight, turn left / right at directional intersection on residential street
Category C	Drive straight through at intersection on major road
	Left / right turn at directional intersection on major road
Category D	Left turn at nondirectional intersection on residential street
	Lane change / merging on residential street
	Right turn at nondirectional intersection on major road
Category E	Lane change / merging on major road
	Highway or driving at higher speed zone
Category F	Enter and exit roundabout on major road
	Lane change on highway / merging onto highway
	Left turn across traffic at nondirectional intersection on major road

*Category B: Low speed maneuver (parking, pulling into curb, and reversing) is excluded from the system due to the complex, various situations that could be included in this category

*Rows in orange indicate maneuvers at intersections; rows in blue indicate lane change or merging; the row in grey indicate driving on highway or at high speed zone.

Table 4.5: Weighting errors in each driving maneuver/environment

Error type	Maneuver/Environ. complexity	Driving maneuver/environment	Error Weighting
No signaling	A	Enter and exit roundabout on residential street	1
		Right turn at nondirectional intersection on residential street	
		Turn left / right at directional intersection on residential street	
	B	Parking/low speed maneuver	1
	C	Left / right turn at directional intersection on major road	2
	D	Left turn at an intersection with a nondirectional light or sign on residential streets	2
		Lane change / merging on residential street	
		Right turn at nondirectional intersection on major road	
	E	Lane change / merging on major road	3
		Highway or driving at higher speed zone	
	F	Enter and exit roundabout on major road	3
		Lane change on highway / merging onto highway	
		Left turn across traffic at nondirectional intersection on major road	
No mirror use	A	Enter and exit roundabout on residential street	1
		Right turn at nondirectional intersection on residential street	
		Turn left / right at directional intersection on residential street	
	C	Left / right turn at directional intersection on major road	2
	D	Left turn at nondirectional intersection on residential street	3
		Lane change / merging on residential street	
		Right turn at nondirectional intersection on major road	
	E	Lane change / merging on major road	3
		Highway or driving at higher speed zone	
	F	Enter and exit roundabout on major road	3
		Lane change on highway / merging onto highway	
		Left turn across traffic at nondirectional intersection on major road	
No looking	A	Drive straight through a nondirectional intersection on residential street	3
		Enter and exit roundabout on residential street	
		Right turn at nondirectional intersection on residential street	
		Drive straight, turn left / right at directional intersection on residential street	
	B	Parking / low speed maneuver	3
	C	Drive straight through at an intersection on major roads	3

		Left / right turn at an intersection with directional lights on major roads	
	D	Left turn at nondirectional intersection on residential street	3
		Lane change / merging on residential street	
		Right turn at nondirectional intersection on major road	
	E	Lane change / merging on major road	3
		Highway or driving at higher speed zone	
	F	Enter and exit roundabout on major road	3
		Lane change on highway / merging onto highway	
		Left turn across traffic at nondirectional intersection on major road	
Driving too fast	A	Drive straight through a nondirectional intersection on residential street	2
		Enter and exit roundabout on residential street	
		Right turn at nondirectional intersection on residential street	
		Drive straight, turn left / right at directional intersection on residential street	
	C	Drive straight through at intersection on major road	2
		Left / right turn at directional intersection on major road	
	D	Left turn at nondirectional intersection on residential street	2
		Lane change / merging on residential street	
		Right turn at nondirectional intersection on major road	
	E	Lane change / merging on major road	2
		Highway or driving at higher speed zone	
	F	Enter and exit roundabout on major road	3
		Lane change on highway / merging onto highway	
		Left turn across traffic at nondirectional intersection on major road	
Driving too slow	A	Drive straight through a nondirectional intersection on residential street	1
		Enter and exit roundabout on residential street	
		Right turn at nondirectional intersection on residential street	
		Drive straight, turn left / right at directional intersection on residential street	
	C	Drive straight through at intersection on major road	2
		Left / right turn at directional intersection on major road	
	D	Left turn at nondirectional intersection on residential street	2
		Lane change / merging on residential street	
		Right turn at nondirectional intersection on major road	
	E	Lane change / merging on major road	3
		Highway or driving at higher speed zone	
	F	Enter and exit roundabout on major road	3

		Lane change on highway / merging onto highway	
		Left turn across traffic at nondirectional intersection on major road	
Missed opportunity	A	Enter and exit roundabout on residential street	1
		Right turn at nondirectional intersection on residential street	
		Turn left / right at directional intersection on residential street	
	C	Left / right turn at directional intersection on major road	2
	D	Left turn at nondirectional intersection on residential street	2
		Lane change / merging on residential street	
		Right turn at nondirectional intersection on major road	
	E	Lane change / merging on major road	2
		Highway or driving at higher speed zone	
	F	Enter and exit roundabout on major road	3
		Lane change on highway / merging onto highway	
		Left turn across traffic at nondirectional intersection on major road	
Unsafe gap	A	Enter and exit roundabout on residential street	2
		Right turn at nondirectional intersection on residential street	
		Turn left / right at directional intersection on residential street	
	C	Left / right turn at directional intersection on major road	3
	D	Left turn at nondirectional intersection on residential street	3
		Lane change / merging on residential street	
		Right turn at nondirectional intersection on major road	
	E	Lane change / merging on major road	3
		Highway or driving at higher speed zone	
	F	Enter and exit roundabout on major road	3
		Lane change on highway / merging onto highway	
		Left turn across traffic at nondirectional intersection on major road	
Failure to yield	A	Enter and exit roundabout on residential street	2
		Right turn at nondirectional intersection on residential street	
	D	Left turn at nondirectional intersection on residential street	3
		Lane change / merging on residential street	
		Right turn at nondirectional intersection on major road	
	E	Lane change / merging on major road	3
		Highway or driving at higher speed zone	
	F	Enter and exit roundabout on major road	3
		Lane change on highway / merging onto highway	
		Left turn across traffic at nondirectional intersection on major road	
Hitting Curb	A	Enter and exit roundabout on residential street	1
		Right turn at nondirectional intersection on residential street	

		Drive straight, turn left / right at directional intersection on residential street	
	C	Left / right turn at directional intersection on major road	2
	D	Left turn at nondirectional intersection on residential street	2
		Lane change / merging on residential street	
		Right turn at nondirectional intersection on major road	
	E	Lane change / merging on major road	3
		Highway or driving at higher speed zone	
	F	Enter and exit roundabout on major road	3
		Lane change on highway / merging onto highway	
		Left turn across traffic at nondirectional intersection on major road	
Non-compliance to road sign	A	Drive straight through a nondirectional intersection on residential street	2
		Enter and exit roundabout on residential street	
		Right turn at nondirectional intersection on residential street	
		Drive straight, turn left / right at directional intersection on residential street	
	C	Drive straight through at intersection on major road	3
		Left / right turn at directional intersection on major road	
	D	Left turn at nondirectional intersection on residential street	3
		Right turn at nondirectional intersection on major road	
	F	Enter and exit roundabout on major road	3
		Left turn across traffic at nondirectional intersection on major road	
Crossing pavement	A	Drive straight through a nondirectional intersection on residential street	1
		Enter and exit roundabout on residential street	
		Right turn at nondirectional intersection on residential street	
		Drive straight, turn left / right at directional intersection on residential street	
	C	Drive straight through at intersection on major road	2
		Left / right turn at directional intersection on major road	
	D	Left turn at nondirectional intersection on residential street	2
		Right turn at nondirectional intersection on major road	
	F	Enter and exit roundabout on major road	3
		Left turn across traffic at nondirectional intersection on major road	
Out of lane	A	Drive straight through a nondirectional intersection on residential street	1
		Enter and exit roundabout on residential street	
		Right turn at nondirectional intersection on residential street	

		Drive straight, turn left / right at directional intersection on residential street	
	B	Parking/low speed maneuver	2
	C	Drive straight through at intersection on major road	3
		Left / right turn at directional intersection on major road	
	D	Left turn at nondirectional intersection on residential street	3
		Lane change / merging on residential street	
		Right turn at nondirectional intersection on major road	
	E	Lane change / merging on major road	3
		Highway or driving at higher speed zone	
	F	Enter and exit roundabout on major road	3
		Lane change on highway / merging onto highway	
		Left turn across traffic at nondirectional intersection on major road	
Inappropriate following distance	D	Lane change /merging on residential street	2
	E	Lane change /merging on major road	3
	F	Lane change on highway / merging onto highway	3

[Note 1] Correspondence of errors occurring during low speed maneuvers (i.e., reversing, pulling into curb, and parking)

- No observation (≈no looking)
- Signaling misuse (≈signaling error)
- Inappropriate positioning attempts (≈out of lane)

[Note 2] Free-driving is only recorded when an error occurs. We consider the complexity level of driving maneuver/environment during free driving is equivalent to:

- On residential streets: Drive straight through with nondirectional intersection (Category A)
- On major roads: Driving straight through with a directional intersection (Category C)
- Highway or high-speed driving (Category E)

CHAPTER 5: MANUSCRIPT #2

Personal and clinical factors associated with older drivers' self-awareness of driving performance

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5.1 Preface

Results of the surveys presented in the previous chapter were used to create two scores for the eDOS tool. The driving maneuver/environment complexity score represents the difficulty of the route choice in each eDOS drive and can be used as a controlling variable when comparing the naturalistic driving performance across clients and evaluation sessions. The weighted eDOS total score represents older drivers' everyday driving performance by accounting for the percentage of driving errors committed during the drive and the risk level of each type of driving error and the corresponding environment where the error occurs. This weighted score is an improvement over the original eDOS total score by providing less weight to habitual errors (e.g. no signaling on residential streets) and more weight to the errors posing greater risk (e.g. lack of environmental verification at a busy intersection). Creating this weighted eDOS score was an important and necessary step to ensure that the following studies conducted in this thesis would have a more accurately measure older drivers' everyday driving performance using the eDOS.

The eDOS was one of the main measures used in this manuscript which aims to examine older drivers' accuracy of self-awareness in their everyday driving environment by determining the concordance between their perceived driving ability (assessed by the Perceived Driving Ability [PDA] questionnaire) and their actual driving performance (assessed by electronic Driving Observation Schedule [eDOS]).

The second objective of this manuscript is to further investigate the characteristic of older drivers who under-, accurately-, and over-estimated their driving ability. Using an ordinal regression model, the association between older drivers' demographic information (i.e. age, gender, and educational level) and clinical factors (i.e. visual, cognitive, psychomotor and executive functioning, mood, comorbid medical conditions) with their accuracy of self-awareness of driving ability were examined.

5.2 Abstract

Most drivers perceive themselves as good drivers, but their perception may not be accurate and could affect their driving safety. This study examined the accuracy of older drivers' self-awareness of driving ability in their everyday driving environment by determining the concordance between their perceived (assessed by the Perceived Driving Ability [PDA] questionnaire) and actual (assessed by electronic Driving Observation Schedule [eDOS]) driving performance and determined the demographic and clinical factors associated with accuracy of self-awareness. One hundred and eight older drivers (male: 67.6%; age: *M*=80.6 years, *SD*=4.9) were classified into 3 groups based on their accuracy of estimation of their driving ability: under-estimation (19%); accurate (29%); over-estimation (53%). An ordinal regression analysis showed that older drivers who over-estimated their driving ability had better visuo-motor processing speed and fewer self-reported comorbid medical conditions, while those who under-estimated their driving ability had worse visuo-motor processing speed and more comorbid medical conditions.

Résumé

La plupart des personnes âgées se considèrent comme de bons conducteurs, mais leur perception n'est peut-être pas valide et pourrait affecter négativement leur sécurité routière. Cette étude a examiné l'exactitude de la prise de conscience des conducteurs âgés en comparant deux évaluations: un questionnaire de Perception de la Capacité de Conduite (PDA) et une observation routière dans l'environnement quotidien de conducteur (eDOS). Nous avons classifié les 108 conducteurs (hommes: 67.6 %; âge: M=80.6 ans, É-T=4.9 ans) qui ont participé à l'étude dans trois catégories: sous-estimation (19%), estimation exacte (29%), surestimation (53%). En utilisant les données démographiques et cliniques de la plateforme Candrive, une régression a identifié deux facteurs qui sont associés avec l'exactitude de la prise de conscience des conducteurs: ceux qui ont surestimé leur aptitude à la conduite avaient un meilleur temps de traitement de l'information visuo-motrice mesuré par le TMT-A et rapportaient avoir moins de comorbidité.

Keywords: aging, self-awareness, driving, comorbidity, perceived driving ability

Mot clés: vieillissement, conscience de soi, conduite automobile, comorbidité, capacité de conduite perçue

5.3 Introduction

In most developed countries, the population is aging and the number of older drivers and their driving mileage per year is growing rapidly (Eby & Molnar, 2009). Drivers aged 75 years and older have a higher crash rate per kilometre driven and higher rates of severe injury and fatal crashes compared to middle-aged drivers (Cicchino & McCartt, 2014). Many older drivers consciously or unconsciously adopt a number of driving modifications, such as avoiding driving in heavy rain or on highways (Bergen et al., 2017; Molnar et al., 2014), in response to age-related functional decline. While these behaviors changes were found to be beneficial for decreasing involvement in crashes (de Raedt & Ponjaert-Kristoffersen, 2000), not all older drivers adopt self-regulatory behaviors to maintain their safety (Molnar et al., 2013).

The accuracy of an individual's self-awareness of their driving ability may be an important factor influencing self-regulatory behaviors (Marottoli & Richardson, 1998). Lack of self-awareness, or anosognosia, is a phenomenon commonly studied among people with traumatic brain injury, dementia, stroke, and other neurological diseases (Chavoix & Insausti, 2017). Many clients with these neurological conditions have no or only partial knowledge about their own impairments and their impact on functional abilities and performance (Goverover, Chiaravalloti, Gaudino-Goering, Moore, & DeLuca, 2009; Okonkwo et al., 2009). Without self-awareness, they are likely to over-estimate their abilities and skills in various activities of daily living, leading to high risk exposure and low motivation towards necessary behavioral or environmental modifications (Gillen, 2009; Lindstrom, Eklund, Billhult, & Carlsson, 2013).

Self-perception reflects one's belief in their own driving ability, which may or may not correspond to their actual driving performance. Older adults have been found to rate their driving ability as better than "other drivers of the same age" or "average drivers", whereas their actual driving ability varies (Freund, Colgrove, Burke, & McLeod, 2005; Marottoli & Richardson, 1998; Selander, Lee, Johansson, & Falkmer, 2011). Older adults who perceive their driving as good and who also have good driving skill, behavior and attitude is not a problem given that they have accurately assessed their own behind-the-wheel competence. However, over-estimating one's driving performance, particularly if they were to drive in a challenging environment which exceeds their ability to control the vehicle, could have negative consequences. In one study using a driving simulator to test older drivers referred to driving rehabilitation clinics, Freund et al. (2005) found that those who over-estimated their driving ability were four times more likely to fail the driving test than those who rated their driving ability the same or worse than other drivers of the same age. Under-estimation can also negatively impact the driver. Older drivers who under-estimated their driving ability were more likely to limit their driving or cease this activity altogether (Meng & Siren, 2012). Following driving cessation, the frequency and freedom of out-of-home mobility and social participation can become limited (Marottoli et al., 2000).

In this context, the accuracy of self-awareness of driving ability is defined as the congruence between an individual's perceived and actual driving ability. For older drivers, having accurate self-awareness involves changing their own perception of driving ability over time in accordance with age-related physical and cognitive decline. This mechanism enables them to adopt effective driving modifications in order to maintain safety without compromising mobility. Nevertheless, most studies have not found a correlation between older adults' perceived driving ability and their actual driving performance (Brown et al., 2005; Hunt, Morris, Edwards, & Wilson, 1993; Marottoli & Richardson, 1998; Riendeau, Maxwell, Patterson, Weaver, & Bedard, 2016; Selander et al., 2011). In previous studies, the types of measures used to capture perceived driving ability and actual driving performance varied. Some asked older drivers to compare their driving ability to others (Broberg & Dukic Willstrand, 2014; Freund et al., 2005; Selander et al., 2011; Windsor, Anstey, & Walker, 2008), which requires an individual to appraise both their own ability and others' abilities, and then make a 'social' comparison. Literature in cognitive psychology has found that a better-than-the-others answer is common in human nature (Reisberg, 2013). Several theories have been published to explain this phenomenon, including optimism bias, self-enhancement bias, downward comparisons, and illusory superiority (Groeger, 2000; Sundström, 2008). Approximately 70% of older drivers perceive their driving ability to be better than others' (Marottoli & Richardson, 1998; Selander et al., 2011), even though some participants were recruited from driving rehabilitation clinics where their driving ability had already been questioned (Freund et al., 2005). Questions that involve social comparisons can lead to inaccurate judgement of one's own ability, and, therefore, may not serve as the best means of capturing an older drivers' subjective measure of driving ability.

Some studies used only a single question to measure drivers' self-perception (e.g., rate the quality of your driving) (Ackerman, Vance, Wadley, & Ball, 2010; Brown et al., 2005; Ross, Dodson, Edwards, Ackerman, & Ball, 2012; Wild & Cotrell, 2003; Wong, Smith, & Sullivan, 2012; Wood, Lacherez, & Anstey, 2013), while others adopted questionnaires which were not specifically designed to assess perception of driving ability (Pachana & Petriwskyj, 2006). For instance, the Deficit Awareness Questionnaire that addresses one's perceived abilities in memory, attention, and everyday activities has been administered to older drivers and their families to examine self-awareness of driving performance (Green, Goldstein, Sirockman, & Green, 1993; Wild & Cotrell, 2003). Although these questions address aspects of driving ability, they are not likely to guide an individual to reflect on their driving performance in different driving conditions and respond specifically about their driving abilities. In fact, self-awareness is "object-dependent", meaning that one's accurate self-perception in one domain does not imply correctness in another domain (Toglia & Kirk, 2000). For example, Marková et al. (2014) reported that levels of accuracy of self-awareness of memory functioning, activities of daily living, and socio-emotional functioning are significantly different among older adults with early-stage dementia. Therefore, it is important to adopt a reliable and valid questionnaire specifically designed to assess older drivers' perception of driving ability. Several available measures have the potential to be used among older drivers. However, one questionnaire is only suitable for clients referred to driving rehabilitation centres (i.e. DriveAware) (Kay, Bundy, & Clemson, 2009), while others were only tested among clients with neurological conditions (i.e. Brain Injury Driving Self-Awareness Measure for clients with brain injury and Adelaide Driving Self-Efficacy Scale for clients with stroke) (George, Clark, & Crotty, 2007; Gooden et al., 2017) or younger adults (i.e. Driving Skill Inventory and Driving Self-Evaluation Questionnaire) (Amado, Arikan, Kaca, Koyuncu, & Turkan, 2014; Lajunen & Summala, 1995). Only the Perceived Driving Ability Questionnaire (PDA) has been validated with a group of older drivers using an on-road driving observation protocol, which showed that older drivers with better driving performance rate their ability higher than poor drivers (Koppel et al., 2016).

Finally, in the literature, standard on-road driving evaluations are typically used as the external, objective criteria to determine the accuracy of one's self-awareness of driving ability (Riendeau et al., 2016). This method is frequently adopted because it is considered the gold standard for measuring driving performance (Di Stefano & Macdonald, 2006) and is free from the subjective bias of proxy-reported driving abilities (Fawcett, 2013). However, due to the strict guidelines of the testing methods and conditions, such as using an unfamiliar vehicle and driving on designated routes guided by a driving instructor in a car with a dual brake, the test results may not represent an older driver's everyday driving performance. Driving performance could be impacted by driving in an unfamiliar vehicle (Lundberg & Hakamies-Blomqvist, 2003), and the standard on-road driving evaluation lacks ecological validity (Chen, Gélinas, & Mazer, 2018). As many older drivers modify their driving conditions and routes in their everyday driving, during the standard on-road evaluation, drivers may have to drive in unfamiliar conditions, such as on highways and busy roads. Most importantly, when asking older drivers to appraise their driving ability, their response relates to their everyday driving may not correspond to their driving during a standard on-road evaluation.

Several factors may be associated with the accuracy of an older driver's self-awareness of their driving ability. Older age was found to be related to over-estimation of driving ability (Marottoli & Richardson, 1998). One study reported that older drivers with better cognitive functioning and executive functioning tended to be more accurate or under-estimate their driving ability (Wood et al., 2013). However, two other studies did not find these same associations (Broberg & Dukic Willstrand, 2014; Freund et al., 2005). These inconsistent results may be related to the varied methods used to measure actual and perceived driving ability. In addition, being female and having a depressive mood have also been linked to lower perceived driving ability (Selander et al., 2011). However, the question remains as to how these factors might influence the accuracy of estimations in actual driving performance.

The primary objective of this study was to determine the accuracy of older drivers' self-awareness of driving ability in their everyday driving environment, as measured by a naturalistic on-road driving observation. Accuracy of self-awareness was defined as the congruence between an individual's perceived driving ability (as measured by the PDA) and actual driving ability (as measured by the electronic Driving Observation Schedule [eDOS]). The secondary objective was to determine the relationship between demographic characteristics (i.e. age, gender, and educational level) and clinical factors (i.e. visual, cognitive, psychomotor and executive functioning, mood, comorbid medical conditions) with self-awareness of driving ability.

5.4 Methods

5.4.1 Study design

This cross-sectional study was built on the infrastructure of the Candrive/Ozcandrive prospective cohort study of older drivers, which tracked the health and driving of 928 Canadians aged 70 years and older (The study protocol is outlined elsewhere, see Marshall et al., 2013).

5.4.2 Participants

Participants from three of the Candrive research sites: Montreal (MTL), Ottawa (OTT), and Hamilton (HML), were invited to participate in this current study. The inclusion criteria for this study were: drivers aged 75 years and older (this study was conducted at the fifth year of the Candrive study); holder of a valid driving license and driving at least once a week; under care of a family physician; and English speaking. Participants were excluded if they had a contraindication to driving, if their Candrive annual assessments were administered more than 200 days before or after the driving observation, or if their PDA questionnaire was not completed within 90 days of the driving observation. The latter two exclusion criteria were adopted because participants' clinical functioning conditions were retrieved from the Candrive annual assessments. It was assumed that the Candrive data retrieved within these defined intervals could reflect participants' functional conditions on the day of the on-road driving observation, as past study reported that there was little variation from year to year (Smith et al., 2013).

5.4.3 Procedure

Participants were recruited by Candrive research assistants at each site in their fifth or sixth year of the cohort study. The purpose and procedures of this current study were explained to eligible participants. Those who agreed to participate were given an appointment to conduct the naturalistic driving observation. Recruitment continued until the target sample size of 50 from each site was reached.

On the day of the naturalistic on-road driving observation, two research assistants visited the participant's home. The driver was asked to sign a consent form (see Appendix 4) and complete the PDA questionnaire, followed by an explanation of the naturalistic on-road observation. The participant was asked to nominate two destinations where they usually visit, choose the route to reach them, and plan to come back home within 20 to 25 minutes. To record their driving behavior, each participant drove their own vehicle and was encouraged to drive as they would usually do, including driving with a “co-pilot” passenger or listening to the radio, if that was their routine. During the observation, the research assistants followed the participant in another vehicle. One research assistant drove the following car, while the other sat in the front passenger seat and observed and recorded the participant’s driving behavior and environment using the eDOS scoring procedure (Koppel et al., 2013; Koppel et al., 2016). If a participant usually avoided driving in certain weather conditions, such as heavy rain or fog, they were given the option of rescheduling their driving observation. Due to logistical constraints, some participants did not complete the PDA on the day of on-road driving observation. In this case, their PDA score was retrieved from the Candrive annual assessment database if the interval between the two evaluations was within 90 days. If not, they were excluded.

The data for the independent variables, including demographic information (i.e. age, gender, and educational level) and clinical factors, were retrieved from the Candrive annual evaluation database. Data was collected from the assessments completed closest to the date of the driving observation for each participant, which was either the fifth or the sixth Candrive annual assessment.

5.4.4 Measurements

The primary outcome measure, self-awareness of driving ability, was derived from the correspondence between older drivers’ perceived driving ability (measured by the PDA) and actual driving ability (measured by the eDOS), respectively (See data analysis section for more details).

Electronic Driving Observation Schedule (eDOS): The eDOS is an observation procedure, designed for use within the Candrive/Ozcandrive cohort study, to enable systematic and reliable observations of on-road driving behavior (Vlahodimitrakou et al., 2013; Koppel et al., 2013; Koppel et al., 2016), and monitoring of potential on-road driving behavior changes over time (Koppel et al., 2017). The eDOS procedure used in this study was modified from the original version to observe and record by an evaluator in a following car (see Appendix 3.3). Using the eDOS scoring procedure, driving behaviors and the environment at each maneuver are systematically recorded on a tablet. Driving maneuvers are categorized as either intersection negotiation, lane-changing, merging, maneuver-free driving or low speed maneuvers. Within each driving maneuver category, corresponding environmental and behavioral variables are recorded. For example, the type of traffic sign or light, driving direction (i.e. going straight through or making a left/right/U-turn), number of lanes, speed limit, and traffic volume are the environmental variables recorded at each intersection. Driving behaviors are coded as appropriate or inappropriate in the following six categories: observation of road environment (no mirror use or no head checking); signalling; speed regulation (too fast or too slow); gap acceptance (missed opportunity, unsafe gap, or failure to yield); road rule compliance (non-compliance with traffic signage or crossing pavement); vehicle or lane position (lane drifting, hitting curb, or inappropriate following distance). In addition, critical driving errors are noted when the participant is involved in a crash or near-crash. Operational definitions of all these factors are provided in a detailed eDOS administration manual (Candrive Research Team, 2017).

A driving maneuver/environment complexity score and a weighted eDOS total score were calculated. Because the route between drivers was not consistent, a driving maneuver/environment complexity score was generated to quantify the overall level of difficulty of each eDOS drive. This score ranges from 1 to 3; higher score indicates more difficult, complex driving maneuvers and environments. A weighted eDOS total score was calculated to represent a driver's overall eDOS driving performance. This score was generated by summing weighted driving errors (1=low risk error to 3=high risk error) based on the error type and risk level in corresponding maneuver/environments. Lower weighted eDOS total scores indicate better driving performance, while higher scores indicate that the driver either committed some severe errors (e.g. choosing an unsafe gap during a lane change on a boulevard) and/or demonstrated several bad driving habits (e.g. no signalling on quiet residential streets for a right turn). There is no maximum number for this score. This weighting system was developed based on a literature review and a two-round on-line survey with experts in the field of driving rehabilitation (for details, see Chen, 2018).

The non-electronic version of the original eDOS has been shown to have good reliability and internal consistency (ICC=0.91, 95% CI=0.75-0.97, $p<0.0001$; $r(18)=0.83$, $p<0.05$)

(Vlahodimitrakou et al., 2013). The eDOS was also acceptable to participants and feasible to administer for observers and it was found to be representative of older drivers' everyday driving routes in an Australian sample (Koppel et al., 2013; Koppel et al., 2016). This evaluation method has not only reliability, face validity, but also ecological validity, as it reflects older drivers' everyday driving ability.

Perceived Driving Ability (PDA): Participants' self-perception of current driving ability was measured using the PDA. This questionnaire is comprised of 15 items asking participants to report their perception of their current ability in both general and specific driving conditions, such as the ability to drive safely, or the ability to see a road sign or make quick decisions. Their ratings are coded from 0 (poor) to 3 (very good). Total scores range from 0 to 45, with higher scores indicating better self-rated driving ability. Missing data were replaced by the total mean score, mean score of certain items, or discarded according to a guideline published by the primary author of this questionnaire (Myers, 2008). Rasch analysis shows this questionnaire is unidimensional and hierarchical with good person and item reliability (r=0.92 and 0.96, respectively) (MacDonald, Myers, & Blanchard, 2008).

Demographic and Clinical Factors: Demographic characteristics included age, gender, and education level. Measures of visual acuity, cognition, psychomotor skills, executive functioning, mood, and comorbid medical conditions were selected because they are known to have an association with on-road driving performance and are commonly used in driving studies (Smith et al., 2013).

Snellen Test. The Snellen Test measures visual acuity. Using a traditional Snellen eye chart, participants were asked to read the letters of eleven different font sizes using both eyes at a 10-foot distance. Visual acuity was scored as 10/X, where X was the corresponding number at the line where the participant was able to read without any errors. 10/10 indicates normal visual acuity, and lower number infers reduced vision. 4/10 with both eyes open is the lowest legal standard for drivers in Canada (Yazdan-Ashoori & Hove, 2010). The Snellen test has high test-retest reliability (r=0.94) (Lovie-Kitchin, 1988).

Montreal Cognitive Assessment (MoCA). The MoCA is a general test of cognition which evaluates executive functions, naming, orientation, attention, language, memory, visuoconstructional skills, and conceptual thinking. The maximum score is 30 points. According to a recent meta-analysis, the cut-off score of 23 for the education-adjusted MoCA total score is used to diagnose older adults with mild cognitive impairment, and this score was applied to describe the cognitive functioning of our sample (Carson, Leach, & Murphy, 2018). The cut-off score of ≤ 25 in the MoCA total score has a sensitivity of 84.5% and a specificity of 50% to discriminate safe and unsafe older drivers (Kwok, Gélinas, Benoit, & Chilingaryan, 2015).

Motor Free Visual Perception Test-3 (MVPT-3): Visual Closure. Participants' visuospatial ability to identify partially obscured objects was measured using the MVPT-3 visual closure subtest (Colarusso & Hammill, 2003). Participants were asked to match the target figure to one of four incomplete drawn objects. Thirteen figure cards are presented, and accuracy is recorded by the number of correct answers (maximum=13). Although no studies have reported the psychometric property of this single item in the MVPT-3 among older drivers, one study reported that the performance of the visual closure subtest in an earlier version, MVPT, is associated with future at-fault vehicle crashes for drivers aged 55 years and older (Ball et al., 2006).

Trail Making Test (TMT). The TMT test examines visual search, scanning, psychomotor speed, mental flexibility, and executive functioning (Bowie & Harvey, 2006; Reiten, 1958). The TMT Part A requires participants to connect 25 numbers that are randomly distributed on a page in numerical order, while part B asks participants to draw lines alternatively between numbers and letters in sequential order (e.g. 1, A, 2, B, 3, C, etc.). Participants are told to finish the two tasks as quickly and as accurately as possible. Time to complete TMT part A and B was recorded to represent visuo-motor processing speed. The TMT has good to high reliability measured by a coefficient of concordance (r=0.78 for part A and r=0.67 for part B) (Lezak, 1983).

Timed Up and Go (TUG). The TUG examines functional mobility (Podsiadlo & Richardson, 1991; Shumway-Cook, Brauer, & Woollacott, 2000). Participants are required to stand up from an armchair, walk 3 m (10 ft), and return to the seated position. Time taken to complete the test is recorded. The TUG has good inter-rater and intra-rater reliability, as well as excellent construct validity with the Berg Balance Scale (r=-0.81), gait speed (r=-0.61), and the Barthel Index of ADL (r=-0.78) (Podsiadlo & Richardson, 1991).

Expanded and Modified Cumulative Illness Rating Scale (mCIRS). The mCIRS assesses one's multimorbidity by taking account of the number and severity of medical conditions (Hudon, Fortin, & Vanasse, 2005; Hudon, Fortin, & Soubhi, 2007). Participants rate the severity of their medical problems on a five-point scale from 0 (no problem) to 4 (extremely severe problem) in 44 body systems and diseases. The number of the comorbid conditions is the sum of all conditions that were identified. The severity score is the sum of the severity ratings for each identified condition. The mCIRS has good inter-rater reliability (ICC=0.81), intra-rater reliability (ICC=0.89), and concomitant validity (r=0.73 - 0.84) (Hudon et al., 2005).

Geriatric Depression Scale (GDS). Participants' depressive symptoms were examined using the GDS-15 (Yesavage et al., 1983). This version of the GDS consists of 15 items about one's mood and energy over the past week. Participants are encouraged to choose the best fitting answer between yes and no. The GDS score ranges from 0 to 15; higher scores indicate greater depressive condition. The GDS has good reliability (r=0.76) (van Marwijk et al., 1995). In this study, participants were dichotomized into a depressive group (≥5 points) and a non-depressive group (<4 points).

5.4.5 Statistical analysis

Data derived from the eDOS, PDA, and participant demographic and clinical factors was compiled and organized using the SPSS 24.0 software.

The numbers and distribution for participants' demographic information, predictive variables and outcome variables were examined using descriptive analysis: means and standard deviations (SDs) were reported for continuous variables, and number and percentages were calculated for dichotomous and categorical variables. The distribution of normality for continuous variables was examined using kurtosis and skewness tests in the SPSS package. Variables that violated normal distribution were analyzed using appropriate non-parametric tests. The differences among the three research sites were compared using a chi-square test for dichotomous variables, Kruskal-Wallis ANOVA for ordinal variables, and ANOVA for continuous variables. The Scheffe method was administered for post-hoc comparisons among continuous variables.

To describe the accuracy level of older drivers' self-awareness of driving ability, a new variable was created. This variable was rated on an ordinal scale that categorized participants into one of three groups: 1) under-estimated, 2) accurate, or 3) over-estimated. The groups were determined by the correspondence between the participants' perceived driving ability (i.e. the total score on the PDA questionnaire) and their actual driving performance (i.e. the weighted eDOS total score). Since the PDA and eDOS scores are on continuous scales, cut-off scores were applied to classify participants' PDA and eDOS scores into three levels. The eDOS cut-off scores were determined at the 25^{th} and 75^{th} percentile of the distribution of eDOS scores to emphasize the differences in participants' naturalistic on-road driving performance. The driving performance of fifty percent of the group was classified as middle range. This method was based on a research paradigm from a series of studies of self-awareness specific to psychology (Kruger & Dunning, 1999). The PDA cut-off scores were determined by a review of the literature and experts' judgement. After an examination of the data, the cut-off scores determined to classify the participants' perceived and actual driving ability were 29 (16^{th} percentile) and 35 (50^{th} percentile) for the PDA, and 10 (25^{th} percentile) and 28 (75^{th} percentile) for the eDOS. Participants whose perceived and actual driving ability corresponded were categorized into the "accurate" self-awareness of driving ability group; those who rated themselves higher than their actual driving performance were categorized into the "over-estimated" group; and those who rated themselves worse than their actual driving performance level were in the "under-estimated" group (Table 5.1). The order of this ordinal outcome measure was under-estimator < accurate estimator < over-estimator with unknown between-group intervals. To examine if the PDA data source (i.e. collected from the day of driving observation or retrieved from the Candrive data) had an effect on participants' PDA score or categories of self-awareness, an independent t-test for the PDA score and a chi-square test for the distribution of self-awareness categories were conducted to compare participants whose PDA data were collected differently.

To examine the extent to which demographic characteristics and clinical factors were associated with self-awareness of driving ability, an ordinal logistic regression was conducted. The ordinal logistic regression is a suitable statistical method to estimate the probability of having a certain outcome on an ordinal scale (i.e. the accuracy level of self-awareness of driving ability) from one or more predictive variables (i.e. the demographic and clinical functioning factors) (Portney & Watkins, 2009). The assumptions of this statistical analysis method were examined individually. To avoid violating the assumption of collinearity, a Pearson correlation matrix was calculated. The assumption of having proportional odds was examined by test of parallel lines to ensure that the predictive model had the same effect on different level of the outcome measure, that was, the under-estimated, accurate, and over-estimated groups.

Predictive variables that entered the ordinal logistic regression were selected according to the results of the univariate analysis or variance tests (p<.05). A chi-square test was used for dichotomous variables, a Kruskal-Wallis ANOVA for ordinal variables, and ANOVA tests for continuous variables. Effect sizes of each predictive variable on the outcome variable were presented using η^2 for ANOVA and Kruskal-Wallis ANOVA, and Cramer's V for chi-square tests. The significance level of $p < 0.05$ was considered statistically significant.

A final ordinal logistic regression model was calculated. The model fit was examined using the -2 log likelihood tests, Pearson and Deviance goodness-of-fit tests. Odds ratios and 95% confidence intervals for the variables that can significantly predict the outcome categories were calculated.

The effect size estimation for the sample size calculation is based on Dawson et al. (2011). The estimated effect size $R^2 = 0.12$, power = 0.8, $\alpha = 0.05$, number of predictors = 7, the minimum required sample size is 103.

5.5 Results

One hundred and forty-five participants completed the eDOS. Of these, 37 were excluded from the analysis due to eDOS recording failure (n=3), not having PDA data within 90 days (n=26), and the closest Candrive annual assessment was completed more than 200 days from the naturalistic on-road driving observation (n=8). As a result, 108 participants were included in the current analysis (Ottawa n=47, Montreal n=40, and Hamilton n=21). There were no significant statistical differences in age, gender, educational level, the PDA and eDOS scores, and the predictive variables between excluded and included participants, except the number of comorbid medical conditions (participants who were excluded had significantly more comorbid medical conditions than included ones; p=0.03).

The participants' mean age was 80.6 years (SD=4.9; range 74-96). The majority (67.6%) were male, and 50% held a graduate or post-graduate degree. Ten participants (9.3%) were categorized as having mild cognitive impairment (Carson et al., 2018); other participants were within the normal range of cognitive functioning. The average interval between the date of the Candrive assessment and the eDOS was 84.2 days (SD=57.7). PDA data for 25 participants (23.1%)

was collected from the Candrive annual assessment; their average interval between PDA and eDOS was 37.6 days (SD=25.2).

There were no statistically significant differences in age, gender, and educational level between participants across the three research sites. Post-hoc analysis showed that participants in Hamilton reported significantly more comorbid medical conditions than participants in Ottawa and Montreal (HML vs. OTT, p=0.03; HML vs. MTL, p=0.02). Better visuospatial ability was found in participants in Ottawa compared to those in Montreal (p=0.03). Participants in Montreal had better visual acuity, but worse eDOS scores compared to those in Ottawa and Hamilton (Visual acuity MTL vs. OTT, p<0.001; MTL vs. HML, p<0.001; eDOS MTL vs. OTT, p=0.01; MTL vs HML, p<0.001). See Table 5.2 for the participants' demographic information, clinical abilities, PDA, and eDOS scores.

The number and percentage of participants in the over-estimated (n=57), accurate (n=31), and under-estimated (n=20) groups is shown in Table 5.3. Between group differences for each predictive variable are presented in Table 5.4. The percentage of males in the under-estimated, accurate, and over-estimated groups were 60%, 74%, and 67%, respectively. No gender or educational level differences were found for the self-awareness groups ($\chi^2(2)$ for gender=1.15, p=0.56; $\chi^2(2)$ for educational level=0.39, p=0.82). There were no significant differences in the maneuver/environment complexity score between the three groups (p=.07). No differences in the PDA score were found between participants who did the PDA on the day of the driving observation and those whose data was retrieved from the Candrive assessment ($t(106)$=1.21, p=0.23). There was no difference in their distribution in each of the self-awareness groups ($\chi^2(2)$=1.35, p=0.51).

Based on the significant level of analysis of variance tests and the correlation matrix, predictors that entered the ordinal logistic regression model were age, mCIRS number, and TMT-A. TMT-B was excluded from the model because of its moderate correlation (Pearson r=0.48, p<.001), similar measurement construct, and lower effect size compared with the TMT-A.

Only data for 106 participants who had no missing data for the selected predictive variables were entered into the ordinal logistic regression model. After examining the significance level of each variable in this model, the factor of age was further excluded because after controlling for the other factors, age did not persist in the model (p=0.28). The final model that included only the TMT-A and the number of comorbid medical conditions showed good model fit (Model fitting

$\chi^2(2)=18.61$, $p<0.001$; Pearson Goodness-of-fit $\chi^2(205)=185.50$, $p=0.41$; Deviance Goodness-of-Fit $\chi^2(205)=175.90$, $p=0.61$). The model did not violate the assumption of ordinal logistic regression (test of parallel lines $\chi^2(2)=0.83$, $p=0.66$).

The estimate of the ORs for the TMT-A and the number of comorbid medical conditions for older drivers' self-awareness of driving ability and their 95% CI are presented in Table 5.5. Controlling for the other variable, older drivers who over-estimated their driving ability had better visuo-motor processing speed, as measured by the TMT-A and fewer self-reported comorbid medical conditions, while those who under-estimated their driving ability had worse visuo-motor processing speed and more comorbid medical conditions.

5.6 Discussion

Previous research on self-awareness of driving ability suggests this construct can be important when it comes to influencing an older driver's decision to modify their everyday driving environment and/or driving behaviors. The primary objective of this study was to examine the accuracy of older drivers' self-awareness of driving ability, by examining the concordance between their perceived driving ability and their actual performance using a naturalistic on-road driving observation.

This study was the first to assess the accuracy of self-awareness of driving ability among healthy, community-dwelling older drivers using a naturalistic on-road driving observation. While previous studies have adopted either a standard on-road driving evaluation (Broberg & Dukic Willstrand, 2014; Riendeau et al., 2016; Selander et al., 2011), driving simulation (Freund et al., 2005), in-office functional assessments (Ackerman et al., 2010; MacDonald et al., 2008), and/or adverse driving history events (Marottoli & Richardson, 1998) to determine the accuracy of older drivers self-awareness of their driving ability, this study used a more ecological method of evaluation. Driving performance was assessed in the participants' own vehicle, in a familiar neighborhood, using routes selected by the participants who were told to drive as they do during their everyday driving without any interference from the evaluator. This method avoided the issue of adapting to an unfamiliar vehicle or simulator and reduced test anxiety that could negatively influence an older driver's performance (Fairclough, Tattersall, & Houston, 2006; Lundberg &

Hakamies-Blomqvist, 2003). This naturalistic approach of assessing driving is known to be acceptable to older drivers as it represents their everyday driving behaviors and environments (Koppel et al., 2013; Smith et al., 2012).

Our results support previous research that found that some older drivers, even those without cognitive impairment, do not perceive their driving ability accurately and that many over-estimated their performance (Broberg & Dukic Willstrand, 2014; Freund et al., 2005; Marottoli & Richardson, 1998; Riendeau et al., 2016; Selander et al., 2011). The proportion of drivers with inaccurate self-awareness (including under- and over-estimation groups) reported in our study was higher compared to previous research (70% vs. 40-50%) (Broberg & Dukic Willstrand, 2014; Freund et al., 2005; Riendeau et al., 2016). This discrepancy may be due to the use of different assessment tools and varied cut-off criteria used to measure and classify level of perceived and actual driving performance. When we examined different subgroups of drivers, we found that those who under-estimated their driving were classified in "average" to "better than average" categories in their actual driving performance (16 out of 17 participants). A higher proportion of participants with low perceived driving ability was identified in our study compared with previous literature (16% vs. 0-8% defined by a bit worse than the other drivers or having poor to fair driving ability) (Freund et al., 2005; Marottoli & Richardson, 1998; Riendeau et al., 2016; Selander et al., 2011). This inconsistency may be related to the type of questions that were used to evaluate perceived driving ability. Since the PDA questionnaire asks participants to rate their driving ability in several common, challenging driving conditions, rather than by one single question, these detailed questions might have triggered participants to self-reflect more deeply on their driving ability, leading to a somewhat lower self-rating (MacDonald et al., 2008; Toglia & Kirk, 2000). Considering the social and economic costs for drivers who under-estimate their driving performance, and limit or stop their driving too soon when they are still "good" drivers, the retraining of the drivers' self-awareness of driving ability would be important to regain their driving confidence and mobility.

The percentage of drivers who over-estimated their driving was also slightly higher than the proportion found in previous study findings (53% vs. 38%-51%) (Broberg & Dukic Willstrand, 2014; Freund & Szinovacz, 2002; Riendeau et al., 2016). Considering that the proportion of drivers with medium to high perceived driving ability was similar to the other research findings (84% vs.

80-100%), this result may be due to the fact that drivers make more habitual errors in the naturalistic driving observation than in a standard on-road driving evaluation. Relative to the standard driving test, drivers in a naturalistic environment were more likely to feel freer to demonstrate their "actual" driving patterns and, as such, bad habits, such as not signaling at a turn or speeding, were more common (Chevalier et al., 2017; Sullivan, Bao, Goudy, & Konet, 2015). Davis et al. (2012) reported that drivers made more errors with a greater severity level in naturalistic environments compared with the standard evaluation condition. As the naturalistic driving observation approach penalized participants for engaging in these bad habits, the higher proportion of over-estimated older drivers is likely to be attributed to the use of a naturalistic driving environment to examine the driving performance of older drivers.

The secondary objective of this study was to identify the relationship between demographic and clinical factors with self-awareness of driving ability. Two clinical factors were found to predict the accuracy level of older drivers' self-awareness of driving ability: visuo-motor processing speed measured by the TMT-A and self-reported number of comorbid medical conditions. Older drivers with slower visuo-motor processing speed and a greater number of comorbid medical conditions tended to under-estimate their driving ability, while those with quicker visuo-motor processing speeds and fewer comorbid medical conditions tended to over-estimate their driving ability. These findings are not consistent with results from previous studies. Broberg and Dukic Willstrand (2014) did not find that visuo-motor processing speed is related to older drivers' accuracy of self-awareness of driving ability. Wood et al. (2013) reported a contradictory finding that drivers who over-estimated their driving ability had lower visuo-motor processing speed and under-estimated drivers had better performance on the TMT-A and B. Given that longer times to complete the TMT-A and B are related to lower PDA scores (Rapoport et al., 2013), one possible explanation for these mixed results is the different on-road driving evaluation approaches used to determine the accuracy level of older drivers' self-awareness. A meta-analysis showed that longer time to complete the TMT-B test is associated with failing a standard on-road driving test (Mathias & Lucas, 2009), but this same relationship was not found between the TMT-B and the eDOS in a study with older Australian drivers (Koppel et al., 2013). Moreover, poorer performance on the TMT-A and B was found to be associated with more self-reported avoidance behaviors in difficult driving situations, less driving frequency (Rapoport et al., 2013), and less annual driving mileage (Stutts, 1998). It is possible that in a naturalistic driving evaluation setting, older drivers may have planned their drive ahead of time to avoid difficult driving conditions (Blanchard & Myers, 2010), which modified their actual driving performance. An older driver with declining visuo-motor processing speed may be more conservative on self-rated driving ability, and is more likely to avoid challenging driving conditions, drive more carefully, and maintain satisfactory driving performance in everyday driving environments. However, this self-protective mechanism cannot be adopted in a standard on-road driving evaluation typically used in previous studies and poor visuo-motor processing speed can only negatively affect the driver's performance. In addition, although the results on the TMT-B were significantly different in each self-awareness group in the univariate analysis, this factor was not maintained in the final regression model due to lower predictive power and its collinearity with the TMT-A.

To our knowledge, no studies have investigated the association between comorbid medical conditions and accuracy of self-awareness of driving ability. Our study was the first indicating that, for community-dwelling older drivers, a lower number of comorbid medical conditions is linked to an over-estimation of driving ability, and more clinical issues are associated with under-estimation of their driving ability. Past evidence demonstrated that older drivers with one or more comorbid medical condition are likely to reduce their driving frequency, trip duration and distance, and the decrease of driving exposure is related to their experience and knowledge of the impact of these comorbid symptoms (Sargent-Cox, Windsor, Walker, & Anstey, 2011).

Age was significantly different across the self-awareness groups when using univariate analyses, but this predictive effect was not maintained after accounting for the other predictive factors (i.e. the TMT-A, number of comorbid medical conditions) in the regression model. Interestingly, we did not find a difference in PDA scores and actual driving ability, nor was there a difference in the accuracy of self-awareness between male and female drivers.

There are several study limitations that should be noted. First, some of the PDA data and all the participants' information of clinical information were retrieved from the Candrive database, which might not have been collected very close to the date of the administration of the naturalistic driving observation. Participants' PDA scores and functional abilities may have changed within the time interval between the two assessment appointments. Nevertheless, participants were only included if they had the PDA questionnaire administered within 3 months and the other assessments within 7 months from the date of the driving observation; recent findings demonstrated that older drivers' perceived driving ability and clinical functioning were stable over one year in the Candrive study (Rapoport et al., 2016; Smith et al., 2013). Also, no differences in the PDA score or the distribution of self-awareness groups was found between participants who had the PDA done on the day of driving observation and those who had their PDA from the Candrive study.

Second, our study findings may not be generalizable to all the drivers in this age group. One of the reasons is that our study participants were recruited by convenience sampling, and those with neurodegenerative diseases were excluded from the study. As a result, our study sample had high education levels and was quite healthy. In addition, participants in this study underwent the Candrive assessments annually, in which their driving-related functional abilities, habits, and attitudes were examined over time. Compared with other older drivers, our study participants had more opportunities to reflect on their driving ability and behaviors, and possibly to modify their driving behaviors accordingly. Their self-awareness of driving ability might have been influenced by their participation in this longitudinal cohort study.

Future studies will be needed to expand our knowledge about the mechanism and impact of self-awareness of driving ability on road safety. It is important to identify whether older drivers' self-awareness of driving ability is adjusted with changes in functional abilities over time. Moreover, the relationship between the accuracy level of self-awareness of driving ability and prospective/retrospective crashes among older drivers should be examined to understand if self-awareness of driving ability influences older drivers' driving safety. It will also be interesting to compare older drivers' self-awareness of driving ability with a younger age group to understand whether older drivers are more biased or more accurate in their self-awareness of driving ability. The findings from this study can help clinicians consider how they might tailor their evaluation process, educational programs, and interventions to improve older drivers' self-awareness of driving ability.

5.7 Conclusion

This study found that most healthy community-dwelling older drivers, did not have accurate self-awareness of their driving ability. In particular, those who had better visuo-motor processing ability and fewer comorbid conditions tended to over-estimate their everyday driving performance, while those who had worse visuo-motor processing speed and more comorbid medical conditions tended to under-estimate their driving ability.

Future research is needed to examine the impact of self-awareness of driving safety, which can be used to inform educational and training programs that aim to improve behind-the-wheel safety of older drivers.

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Table 5.1: Classification of accuracy of self-awareness of driving ability

		Perceived driving ability (PDA)		
		Low (0-29)	Median (30-35)	High (36-45)
Actual driving performance (eDOS)	Poor (>28)	Accurate	Over-estimated	Over-estimated
	Average (11-28)	Under-estimated	Accurate	Over-estimated
	Above average (0-10)	Under-estimated	Under-estimated	Accurate

Table 5.2: Participants' demographic characteristics and scores on clinical and driving tests

	N	Mean (SD)	Range
Age	108	80.58 (4.87)	74-96
Snellen test	107	0.80 (0.29)	0.4-1.54
MoCA total score	107	26.18 (2.30)	19-30
MVPT-3 correct responses	106	11.03 (1.61)	7-13
TMT-A time to complete (secs)	106	40.04 (10.70)	22-70
TMT-B time to complete (secs)	104	99.75 (48.05)	52-348
TUG (secs)	95	10.59 (2.93)	6-22
mCIRS: number	108	10.50 (5.33)	2-24
mCIRS: severity	108	15.04 (7.72)	2-37
GDS	107	0.83 (1.27)	0-6
PDA total score	108	35.36 (5.66)	22-45
Weighted eDOS total score	108	20.26 (12.53)	0-60

eDOS: electronic Driving Observation Schedule; GDS: Geriatric Depression Scale; mCIRS: modified Cumulative Illness Rating Scale; MoCA: Montreal Cognitive Assessment; MVPT: Motor-Free Visual Perception Test; PDA: Perceived Driving Ability; TMT: Trail Making Test; TUG: Timed-Up and Go

Table 5.3: Distribution of over-estimated, accurate, and under-estimated participants

		PDA		
		Low	Median	High
eDOS	Poor	1 (0.9%)	15 (13.9%)	12 (11.1%)
	Average	12 (11.1%)	18 (16.7%)	30 (27.8%)
	Above average	4 (3.7%)	4 (3.7%)	12 (11.1%)

eDOS: electronic Driving Observation Schedule; PDA: Perceived Driving Ability

Table 5.4: Demographic and clinical factors according to different levels of self-awareness of driving ability

	Self-awareness	n	Mean (SD) or n (%)	F or χ^2	*p*	η^2 or V
Age	Under	20	82.50 (6.01)	3.54	0.04*	0.06
	Accurate	31	81.32 (4.75)			
	Over	57	79.51 (4.25)			
Visual acuity	Under	19	0.71 (0.24)	2.34	0.10	0.04
	Accurate	31	0.76 (0.27)			
	Over	57	0.85 (0.30)			
MoCA total	Under	19	26.50 (1.96)	1.07	0.35	0.02
	Accurate	30	25.67 (2.22)			
	Over	51	26.18 (2.30)			
MVPT-3 correct	Under	20	11.10 (1.71)	.03	0.98	<0.001
	Accurate	30	11.00 (1.89)			
	Over	56	11.02 (1.43)			
TMT-A	Under	20	45.05(13.58)†	5.96	<0.001*	0.10
	Accurate	30	42.57 (10.77)			
	Over	56	36.89 (8.43)†			
TMT-B	Under	20	117.55 (57.64)	3.65	0.03*	0.07
	Accurate	29	109.10 (59.78)			
	Over	55	88.35 (32.93)			
TUG	Under	19	11.53 (3.20)	1.63	0.20	0.03
	Accurate	26	10.77 (3.29)			
	Over	50	10.14 (2.57)			
mCIRS: Number	Under	20	13.25 (5.52)†	4.78	0.01*	0.08
	Accurate	31	11.06 (5.12)			
	Over	57	9.23 (5.03)†			
mCIRS: Severity	Under	20	18.05 (7.50)	2.89	0.06	0.05
	Accurate	31	15.87 (7.90)			

	Over	57	13.53 (7.45)				
GDS			GDS<4	GDS≥5	0.59	0.75	0.07
	Under	20	19 (95.0%)	1 (5.0%)			
	Accurate	31	30 (96.8%)	1 (3.2%)			
	Over	56	55 (98.2%)	1 (1.8%)			

*$p<0.05$

†Significant between-group differences using Scheffe post-hoc analysis

GDS: Geriatric Depression Scale; eDOS: electronic Driving Observation Schedule; mCIRS: modified Cumulative Illness Rating Scale; MoCA: Montreal Cognitive Assessment; MVPT: Motor-Free Visual Perception Test; TMT: Trail Making Test; TUG: Timed-Up and Go

Table 5.5: Model estimation and ORs for significant predictive variables of older drivers' accurate level of self-awareness

	Wald	df	*p*	OR	95% CI
TMT-A	9.03	1	0.003	0.95	0.91-0.98
mCIRS_N	7.18	1	0.007	0.91	0.84-0.97

CI: confidence interval; df: degree of freedom; OR: odds ratio

mCIRS_N: number of comorbid conditions measured using the modified Cumulative Illness Rating Scale; TMT-A: Trail Making Test-Part A

CHAPTER 6: MANUSCRIPT #3

Longitudinal changes in older drivers' self-awareness of driving ability

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This manuscript is in preparation for submission.

6.1 Preface

Manuscript #2 (Chapter 5) presents a cross-sectional study examining older drivers' self-awareness of driving ability and its associated demographic and clinical factors. Results from this manuscript revealed that most older drivers over-estimate their driving ability, and these drivers tend to have better visuo-motor processing speed and fewer self-reported comorbid medical conditions.

To expand our understanding of this topic, a longitudinal study was conducted to illustrate older drivers' self-awareness of changes in driving ability over one-year period of time. To date, no longitudinal studies using naturalistic driving observation have examined older drivers' self-awareness of changes in driving ability.

Therefore, the objectives of this manuscript were: 1. to describe older drivers' self-awareness of changes in driving ability over one year, and 2. to determine the association between self-awareness and demographic characteristics and changes in clinical functioning.

Findings in this manuscript can further our knowledge toward understanding the characteristics of older drivers who can or cannot accurately modify their perception of driving ability according to changes in their actual driving performance over time and has the potential to inform clinicians about how they can detect older drivers who have higher potential to over- or under-estimate their driving ability over time.

6.2 Abstract

Older drivers' self-awareness of driving ability can trigger self-regulatory behaviors and modify their everyday driving performance. To date, no longitudinal study has examined older drivers' self-awareness of changes in driving ability over time and identified the characteristics of drivers who can accurately monitor the changes. Sixty older drivers (Age: Mean=80.3 years at the first session, SD=5.5; male: 70%) were recruited and categorized into four groups based on the correspondence of changes in perceived and actual driving ability over one year: nearly half of the participants had stable perceived and actual driving ability over time, one-third could not detect worse driving performance and over-estimated their driving ability, and the remainder either accurately detected their poorer driving performance or under-estimated their stable driving performance. None of the demographic or clinical factors were associated with older drivers' self-awareness of changes in driving ability over time, except mental processing and executive functioning (measured using the Trail Making Test) which showed a marginal effect. Study limitations and clinical implications are discussed.

Keywords: aging, self-awareness, driving, longitudinal changes

6.3 Introduction

The population is aging in most developed countries, and the number of older drivers is expected to increase substantially over the next few decades (Langford & Koppel, 2006). The driving license rate for drivers over 65 years of age is projected to increase 40% to 93% from the year of 2000 to 2030 in various high-income countries (Organisation for Economic Co-Operation and Development, 2001). The upcoming cohort of older drivers also tends to drive longer and farther distances compared to earlier cohorts (Newbold, Scott, Spinney, Kanaroglou, & Páez, 2005; Santos, McGuckin, Nakamoto, Gray, & Liss, 2011). The increasing number of older drivers and their rising driving exposure have led to public concern about their driving safety.

Driving is an important occupation for older drivers, but it can be a challenging for some. On one hand, many older drivers value driving as their primary and most preferred mode of transportation to maintain their outdoor mobility and independence (Turcotte, 2009). Also, driving cessation is related to a plethora of negative psychosocial consequences, such as decreased out-of-door activities (Marottoli et al., 2000), isolation and loneliness (Azad, Byszewski, Amos, & Molnar, 2002), as well as depression (Ragland, Satariano, & MacLeod, 2005). On the other hand, as one ages, their driving capacity may be negatively affected by age-related health problems, including impairments in ocular function (Wood & Black, 2016), slower visual processing speed (Owsley et al., 1998), declines in cognitive function (Mathias & Lucas, 2009), or increased prevalence of general medical conditions (e.g. heart disease, diabetic neuropathy) and medications (McGwin, Sims, Pulley, & Roseman, 2000). Compared to middle-aged drivers, drivers over 75 years have higher crash rates per kilometre driven (Cicchino & McCartt, 2014). Their fatality rates are also higher than middle-aged drivers' due to decreased ability to tolerate the impact and recover from a car crash (Li, Braver, & Chen, 2003). For health care professionals, it is important to find the balance between older drivers' individual needs and the public traffic safety by keeping them driving safer and longer and preparing them for driving retirement as early as possible (e.g. explore and familiarize the other mode of transportations) (Oxley & Whelan, 2008).

Beliefs, self-awareness, and self-monitoring of driving capacity was proposed to be one of the key factors to reach this goal of maintaining safe driving for as long as possible. According to the Driving as an Everyday Competence Model (Lindstrom-Forneri, Tuokko, Garrett, & Molnar, 2010) and the Multifactorial Model for Enabling Driving Safety (Anstey, Wood, Lord, & Walker, 2005), even if an older adults' driving capacity is declining, those who can monitor their changes in driving-related visual, cognitive, and psychomotor functioning over time and have an accurate awareness of their own driving ability are more likely to adopt proper strategic or tactical self-regulatory behaviors, enabling them to drive safer and longer. For example, a male older driver who is aware of his poorer vision due to macular degeneration may postpone an appointment to avoid driving in heavy rains with poor visibility; a female older driver who believes her mobility and reaction speed are declining may avoid driving in complex traffic conditions, such as driving during rush hour or on highways. These self-regulatory behaviors are likely to decrease older drivers' crash risk by narrowing the gap between their declining driving capacity with the choice of driving in less challenging routes and environments (de Raedt & Ponjaert-Kristoffersen, 2000).

Nevertheless, not every older driver with functional decline is aware of these changes in driving capacity and may not adopt self-regulatory behaviors (Molnar et al., 2013). Even if they do, their self-regulatory behaviors may not be sufficient to counterbalance their deteriorating driving ability (Ross et al., 2009) or can cause them to prematurely retire or avoid driving before they become unfit to drive (Charlton et al., 2006; Siren & Haustein, 2016). While many research studies have reported that older drivers' self-regulatory behaviors are associated with their rating of self-efficacy (Ackerman, Vance, Wadley, & Ball, 2010), perceived driving ability (Blanchard & Myers, 2010), and comfort level experienced in driving (Meng & Siren, 2012), they may not necessarily be related to their actual visual, physical, and cognitive functioning (Ackerman et al., 2010; Rapoport et al., 2013). It was suggested that one's perception or beliefs in driving ability, despite a trigger of self-regulatory behaviors, may not be accurate and can either facilitate or hinder an older adult's driving performance. To date, only one factor has been found to be moderately related to older drivers' perceived driving ability and their self-regulatory behaviors: better psychomotor processing speed and executive function is associated with better perception of driving ability and higher frequency to drive in complex driving conditions (Lajunen, Corry, Summala, & Hartley, 1998; Rapoport et al., 2013; Rapoport et al., 2016).

Instead of one's belief or perception of driving ability, the correspondence between a driver's perceived and actual driving ability (i.e., the accuracy of self-awareness of driving ability) may be a more crucial indicator of driving behavior and safety (Sundström, 2008). The accuracy of self-awareness of driving ability is commonly measured by comparing one's perceived ability to their actual driving performance. Driving performance may be measured by the number of errors or pass/fail in a driving simulation, an on-road driving evaluation, or a naturalistic driving observation (Pachana & Petriwskyj, 2006). If one perceives his or her own driving ability better than their actual performance (i.e. over-estimation), this may lead to higher risk exposure and lower motivation toward self-regulatory behaviors (Gillen, 2009; Lindstrom, Eklund, Billhult, & Carlsson, 2013). On the other hand, a lower perception of driving ability compared to actual performance (i.e. under-estimation) could cause premature driving limitation and cessation (Meng & Siren, 2012). By recognizing whether an older driver over-, accurately-, or under-estimates his or her own driving ability, it will be possible for clinicians to tailor driving retraining programs towards individual's accuracy of self-awareness for improving their driving performance.

Our previous study explored the demographic and clinical factors associated with an older driver's accuracy of self-awareness of driving ability (Chen et al., 2018). Findings from this cross-sectional study showed that older drivers with better visuo-motor processing speed and fewer medical problems tend to over-estimate their driving ability as measured using a naturalistic driving observation, whereas worse performance in processing speed and more comorbid conditions are associated with under-estimation of driving ability. However, to date, the characteristics of older drivers who can and cannot accurately monitor their changes in driving performance over time, has not been studied. The objectives of this study are: 1. to describe older drivers' self-awareness of changes in driving ability over one year, and 2. to determine the association between changes in self-awareness and demographic characteristics and changes in clinical functioning.

6.4 Methods

6.4.1 Study design

This longitudinal study was built on the infrastructure of the Candrive national cohort study. Participants' perceived and actual driving ability were evaluated and related clinical factors were retrieved from the Candrive database over one year.

6.4.2 Participants

Participants were recruited from three Candrive sites: Hamilton, Montreal, and Ottawa. The inclusion criteria were: drivers aged 74 years and older; holder of a valid driving license who drove at least once a week; under care of a family physician; and English speaking. Participants were excluded if they had a severe contraindication to driving, or if their perceived driving ability questionnaire was not completed within 90 days of the driving observation. It was assumed that the data retrieved within the defined interval reflected participants' perceived driving ability on the day of the driving observation, as there was little variation for this variable from year to year (Rapoport et al., 2016).

6.4.3 Procedure

Participants were recruited to the Candrive study in 2009. Each year, they returned to the research centres and completed a comprehensive assessment of driving-related visual, cognitive, physical functioning, attitude, and history. Marshall et al. (2013) provided a detailed description of the Candrive longitudinal study.

In the fourth year of the Candrive study, a sub-project of observing older drivers' naturalistic driving performance was launched in three Candrive sites. Research assistants at these sites explained the purpose and procedures of this study to eligible participants. Those who agreed to participate were given an appointment to conduct the driving observation. Recruitment continued until the target sample size of 50 from each site was reached.

On the day of observation, two research assistants visited the participant's home. Each participant was asked to sign a consent form and complete the Perceived Driving Ability (PDA) questionnaire. A research assistant explained the procedures for the naturalistic observation of their driving behavior in their everyday environment. The participant was asked to nominate two destinations where they usually visit, choose the route to reach them, and plan to come back home within 20 to 25 minutes. To record their naturalistic driving behavior, the participant drove their own vehicle and was encouraged to drive as they would usually do, including driving with a "co-pilot" passenger or listening to the radio, if that was their routine. During the observation, the two research assistants followed the participant in another vehicle. One research assistant drove the following car, while the other sat in the front passenger seat and observed and recorded the participant's driving behavior and environment using the electronic Driving Observation Schedule (eDOS). If a participant usually avoids driving in certain weather conditions, such as heavy rain or fog, they were given the option of rescheduling their driving observation. Some participants did not complete the PDA questionnaire on the day of driving evaluation. In this case, their PDA score was retrieved from the Candrive annual assessment database if the interval between the two evaluations was within 90 days. If not, those participants were excluded. The same protocol was repeated one year later (+/- one-month).

Demographic information (i.e. age, gender, and educational level) and clinical factors were retrieved from the Candrive annual evaluation database. Data was collected from the Candrive assessment that had closest date from each of the driving observation for every participant.

6.4.4 Measurements

The primary outcome measure, older drivers' self-awareness of changes in driving ability, was derived by comparing the correspondence between their perceived driving ability (measured by the PDA) and actual driving ability (measured by the eDOS) (see data analysis section for more details).

Electronic Driving Observation Schedule (eDOS). The eDOS (Vlahodimitrakou et al., 2013) is an observational tool designed to monitor older drivers' driving performance in their naturalistic environment. Using the eDOS scoring sheet, driving behaviors and the environment at each maneuver are systematically recorded on a tablet. Driving maneuvers are categorized as either intersection negotiation, lane-changing, merging, maneuver-free driving or low speed maneuvers. Within each driving maneuver category, corresponding environmental and behavioral variables are recorded. For example, the environmental variables recorded at each intersection may include the type of traffic sign or light, driving direction (i.e. going straight through or making a left/right/U-turn), number of lanes, speed limit, and traffic volume. Driving behaviors are coded as appropriate or inappropriate in the following six categories: observation of road environment (no mirror use or no head checking); signalling; speed regulation (too fast or too slow); gap acceptance (missed opportunity, unsafe gap, or failure to yield); road rule compliance (non-compliance with traffic signage or crossing pavement); vehicle or lane position (lane drifting, hitting curb, or inappropriate following distance). In addition, critical driving errors are noted when the participant is involved in a crash or near-crash. Operational definitions of all these factors are provided in a detailed eDOS administration manual (Candrive Research Team, 2017).

Using the eDOS recordings, a driving maneuver/environment complexity score and a weighted eDOS total score were calculated. The driving maneuver/environment complexity score was generated to quantify the overall level of difficulty of each eDOS drive since the route taken by different drivers was not consistent. This score ranges from 1 to 3; higher score indicates more difficult, complex driving maneuvers and environments. The weighted eDOS total score was calculated as a measure of a driver's overall eDOS driving performance by summing the weighted error scores. The weighted error score was generated by examining the level of severity in corresponding maneuver/environments for each recorded error. Every low-, moderate-, and high-risk error was assigned a weight from 1 to 3. Lower modified eDOS total scores indicate better driving performance, while higher scores imply that the driver either committed some severe errors (e.g., choosing an unsafe gap during a lane change on a boulevard) or demonstrated several bad driving habits (e.g., no signalling on quiet residential streets when turning right). The weighting system for these two scores was developed based on a literature review and a two-round on-line survey with experts in the field of driving rehabilitation (for details, see Chen, 2018).

The non-electronic version of the eDOS has been shown to have good reliability and internal consistency (ICC=0.91, 95% CI=0.75-0.97, $p<0.0001$; $r(18)=0.83$, $p<0.05$) (Vlahodimitrakou et al., 2013). The eDOS itself was also acceptable to participants and feasible to administer for observers and it was found to be representative of older drivers' everyday driving routes in an Australian sample (Koppel et al., 2013). This evaluation method has not only reliability, face validity, but also ecological validity, to demonstrate older drivers' everyday driving ability.

Perceived Driving Ability (PDA): Current ability. Participants' self-perception of their current driving ability was measured using the PDA questionnaire. This questionnaire is comprised of 15 items asking participants to report their perception of their current ability in both general and specific driving conditions, such as the ability to drive safely, or the ability to see a road sign or make quick decisions. Their ratings are coded from 0 (poor) to 3 (very good). Total scores range from 0 to 45, with higher scores indicating better self-rated driving ability. Missing data are replaced by the total mean score, mean score of certain items, or discarded according to a guideline published by the primary author of this questionnaire (Myers, 2008). Rasch analysis shows this questionnaire is unidimensional and hierarchical with good person and item reliability (r=0.92 and r=0.96, respectively) (MacDonald, Myers, & Blanchard, 2008).

Demographic and Clinical Factors: Demographic characteristics included age, gender, and education level. Visual acuity, contrast sensitivity, cognition, psychomotor skills, executive functioning, and comorbid conditions were assessed because they have known to have an association with on-road driving performance and are commonly used in driving studies (Smith et al., 2013).

Snellen Test. The Snellen Test measures visual acuity. Using a traditional Snellen eye chart, participants were asked to read the letters of eleven different font sizes using both eyes at a 10-foot distance. Visual acuity was scored as 10/X, where X was the corresponding number at the line where the participant was able to read without any errors. 10/10 indicates normal visual acuity, and lower numbers infer reduced vision. 4/10 with both eyes open is the lowest legal standard for drivers in Canada (Yazdan-Ashoori & Hove, 2010). The Snellen test has high test-retest reliability (r=0.94) (Lovie-Kitchin, 1988).

Pelli-Robson Contrast Sensitivity Test. This test examines the contrast sensitivity by testing one's ability to read a chart of letters with fading black ink (Pelli, Robson, & Wilkins, 1988). The score ranges from 0.00 to 2.10, where scores equal to or lower than 1.25 indicates impairments in contrast sensitivity and increased crash risk (Owsley, Stalvey, Wells, Sloane, & McGwin Jr, 2001). The test-retest reliability is high among healthy older adults (Elliott, Sanderson, & Conkey, 1990).

Montreal Cognitive Assessment (MoCA). The MoCA is a general test of cognition which evaluates executive functions, naming, orientation, attention, language, memory, visuoconstructional skills, and conceptual thinking. The maximum score is 30 points. The cut-off score of ≤25 in the MoCA total score has a sensitivity of 84.5% and a specificity of 50% to discriminate safe and unsafe older drivers (Kwok, Gélinas, Benoit, & Chilingaryan, 2015).

Motor Free Visual Perception Test-3 (MVPT-3): Visual closure subtest. Participants' visuospatial ability to identify partially obscured objects was measured using the MVPT-3 visual closure subtest (Colarusso & Hammill, 2003). Participants were asked to match the target figure to one of four incompletely drawn objects. Thirteen figure cards are presented, and accuracy is recorded by the number of correct answers (maximum=13). Although no studies have reported the psychometric property of this single item in the MVPT-3 among older drivers, one study found that the performance of the visual closure subtest in an earlier version, MVPT, is associated with future at-fault vehicle crashes for drivers aged 55 years and older (Ball et al., 2006).

Trail Making Test (TMT). The TMT test examines visual search, scanning, psychomotor speed, mental flexibility, and executive functioning (Bowie & Harvey, 2006; Reiten, 1958). The TMT Part A requires participants to connect 25 numbers that are randomly distributed on a page in numerical order, while part B asks participants to draw lines alternatively between numbers and letters in sequential order (e.g. 1, A, 2, B, 3, C, etc.). Participants are told to finish the two tasks as quickly and as accurately as possible. Time to complete TMT part A and B was recorded to represent visuo-motor processing speed. The TMT has good to high reliability measured by a coefficient of concordance (r=0.78 for part A and r=0.67 for part B) (Lezak, 1983).

Timed Up and Go (TUG). The TUG examines functional mobility (Podsiadlo & Richardson, 1991; Shumway-Cook, Brauer, & Woollacott, 2000). Participants are required to stand up from an armchair, walk 3 m (10 ft), and return to the seated position. Time taken to complete the test is recorded. The TUG has good inter-rater and intra-rater reliability, as well as excellent construct validity with the Berg Balance Scale (r=-0.81), gait speed (r=-0.61), and the Barthel Index of ADL (r=-0.78) (Podsiadlo & Richardson, 1991).

Expanded and Modified Cumulative Illness Rating Scale (mCIRS). The mCIRS assesses one's multimorbidity by taking account of the number and severity of medical conditions (Hudon, Fortin, & Vanasse, 2005; Hudon, Fortin, & Soubhi, 2007). Participants rate the severity of their medical problems on a five-point scale from 0 (no problem) to 4 (extremely severe problem) in 44 body systems and diseases. The number of the comorbid conditions is the sum of all conditions that were identified (i.e. rated between 1 and 4). The severity score is the sum of the severity ratings. The mCIRS has good inter-rater reliability (ICC=0.81), intra-rater reliability (ICC=0.89), and concomitant validity (r=0.73 - 0.84) (Hudon et al., 2005).

6.4.5 Statistical analysis

Data derived from the eDOS, PDA questionnaire, and the Candrive database were compiled and organized using the SPSS 24.0 software.

Numbers and distributions for participants' demographic information, scores of clinical functional assessments, PDA, eDOS driving maneuver/environmental complexity score and weighted eDOS score at the two observation sessions, as well as the change scores for each variable over one year were examined using descriptive analysis: means and standard deviations (SDs) were reported for continuous variables; number and percentages were calculated for dichotomous and categorical variables. For the main outcome measure, the PDA and eDOS variables, the interquartile range (IQR) were also presented. The distributions of normality of continuous variables were examined using kurtosis and skewness tests. Variables that violated normal distribution were analyzed using appropriate non-parametric tests. Changes between the two sessions for these variables were examined by paired t-test. The differences among the three research sites were compared using a chi-square test for dichotomous variables, Kruskal-Wallis ANOVA for ordinal variables, and ANOVA for continuous variables. The Scheffe method was administered for post-hoc comparisons among continuous variables.

To determine older drivers' accuracy of self-awareness of changes in driving ability, the correspondence between the PDA and the eDOS change scores was examined. We defined that the PDA or eDOS change score below one standard deviation for this sample indicates worse perceived or actual driving ability over one year. Otherwise, the drivers categorized as having the same or better perceived or actual driving ability. Four different groups were created (see Figure 6.1). The first group (upper left quadrant) includes drivers whose driving performance was worse at the second evaluation and who were aware of their changes; group two (upper right quadrant) are those who were unaware of their worse driving performance; group three (lower left quadrant) consisted of drivers who thought their driving ability had become worse, but their actual driving performance remain stable; and the fourth group (lower right quadrant) were the drivers who had no changes in perceived and actual driving ability over one year.

To address the second research objective, demographic information and initial and changes in clinical factors were examined by group. Variables that fit the normal distribution were analyzed using ANOVA tests, and the Kruskal-Willis test was used for variables that violated normal distribution. Since the data on clinical factors were retrieved from the Candrive annual assessment, rather than measured on the day of driving observations, participants with Candrive assessments that were administered more than 200 days before or after any of the driving observation were not included in this analysis. This was to ensure the retrieved data represented participants' clinical functioning on the day of driving, as past study reported that the variation of these clinical factors is small (Smith et al., 2013).

6.5 Results

One hundred and sixty-two participants attended the first driving observation, and 142 of them participated in the follow-up drive one year later. Among these participants, only 60 participants who had valid PDA and eDOS data in both evaluation sessions were included in this study. Reasons for excluding participants were: eDOS recording failure at the first driving observation (n=2) or at the 2nd observation (n=3); PDA was not completed within 90 days from the driving at the 1st observation (n=79) and at the 2nd observation (n=42).

The mean age of the 60 participants at the first driving observation was 80.3 years (SD=5.5 years); 42 (70%) were male. Their educational level varied from grade school (n=6, 10%) to post-graduate degree (n=18, 30%). Participants were from Ottawa (n=21, 35.0%), Montreal (n=22, 26.7%), and Hamilton (n=17, 28.3%).

The PDA data for the first observation session was retrieved from the fourth or the fifth year of the Candrive annual assessments. The mean interval between the Candrive assessment and the driving observation was 35.4 (SD=21.6) days. For the second session, the majority (66.7%) of the participants had their PDA questionnaire completed on the day of driving observation, while data for the other participants' was retrieved from the fifth or sixth Candrive annual assessment. The mean interval for this session was smaller than session one, 10.6 (SD=20.1) days. PDA scores were not significantly different from each data source (i.e. retrieved from the Candrive databased or administered on the day of observation) for each session (Session 1: t=0.38, p=0.74; session 2: F=1.71, p=0.19).

The average interval between the first and second driving observation session was 12.1 months (SD=1.0, range=11.6-12.4 months). At the second session, four participants (three from

Montreal and one from Ottawa) did not have their Candrive assessment completed within 200 days before or after the driving observation. They were considered missing valid clinical data at the second session and their change scores in the clinical factors were not calculated and included in this portion of the analysis. The total score of the PDA questionnaire, weighted eDOS score, complexity of eDOS driving route and the performance in each clinical functioning assessment at sessions one and two, as well as the change scores and the paired t-test results between the two sessions, are presented in Table 6.1 and Table 6.2. Comparing the two sessions, older drivers had worse driving performance ($p<0.001$) and MoCA score ($p=0.03$), while there were no changes in their perceived driving ability ($p=0.5$) and the complexity of the eDOS driving routes ($p=0.2$).

No age or gender differences were found among the three research sites (Age: F=0.74, p=0.48; gender: $\chi 2=0.02$, p=0.99). Participants in Hamilton had a higher educational level compared to drivers in Ottawa (F=3.24, p=0.05). The three sites differed in the changes in eDOS performance over one year (Kruskal-Willis $\chi 2=0.1$, $p=0.002$). The decline in driving performance was significantly larger in Montreal drivers than drivers in the other two sites (Montreal vs. Ottawa: $p=0.002$; Montreal vs. Hamilton: $p=0.006$). Changes in their driving route complexity were not statistically significantly different (F=2.7, $p=0.08$), although participants in Ottawa chose to drive on more complex routes at the second session and participants in the other two sites drove on less complex routes. Differences were also found in changes in the PDA scores (F=4.0, $p=0.02$). Post-hoc analysis showed Ottawa and Montreal differed from each other, where drivers in Ottawa had higher perceived driving ability scores at the second session and drivers in Montreal perceived their driving ability to have declined over one year ($p=0.03$). There were no differences in the changes in any of the clinical functioning measures between the three sites.

Using below one standard deviation of the PDA and eDOS change scores, participants who increased more than 12.3 points in the weighted eDOS score were considered to have worse driving performance over one year and a decrease in PDA scores more than 4.8 points were categorized as having worse perception of driving ability over one year. The distribution of the eDOS change and PDA change scores, as well as the cut-off scores are presented in Figure 6.2 and Table 6.3.

To respond to the second study objective, to examine if older drivers' self-awareness in changes in driving ability is associated with their demographic characteristics, the initial and the changes in visual, cognitive, psychomotor abilities and comorbid medical conditions were examined over one year. In order to select proper statistical analysis methods, the distribution and homogeneity of the initial and changes in the age and clinical functional performances among the four awareness groups were examined. None of the factors violated the homogeneity. However, data for contrast sensitivity was lacking variability: 47 out of 60 participants (78%) had the same rating at the first session and 43 out of 50 participants (86%) had no changes in their performance. This factor was therefore not included in this analysis.

Results showed that there were no differences in age, gender, and educational level among the four different awareness groups (Age: F=0.44, p=0.73; gender: χ^2=4.42, p=0.21; educational level: χ^2=17.29, p=0.29). There were no significant differences in their driving maneuver and environment complexity at the first session and in the changes between the two sessions among the groups (Session 1: F=1.42, p=0.24; changes: F=0.43, p=0.73). No group differences were found in any of the clinical functioning at the first session and the changes in the clinical functioning over one year. One exception was that the TMT-B test at the first session reached a marginal difference (F=2.27, p=0.06). The group that was over cautious (under-estimated) and rated their driving performance as worse while their driving performance was stable over one year, had the worst performance in processing speed and executive function (i.e. group 3), followed by the stable group (i.e. group 4). Participants who had worse driving performance at the second session, regardless of their perceived changes in driving ability, had better processing speed and executive functioning (i.e. group 1 and 2). Detailed group differences among the initial and changes in clinical factors are presented in Table 6.4 and Table 6.5, respectively.

6.6 Discussion

This study examined older drivers' self-awareness of changes in driving ability over time. Using the correspondence between their changes in perceived and actual driving ability over one year, participants were classified into four groups: accurate estimation of worse driving performance, over-estimation of worse driving performance, under-estimation of stable driving performance, and accurate estimation of no changes in driving performance. The second objective was to identify the demographic (i.e. age, gender, and educational level) and clinical factors (i.e. visual, cognitive, executive, psychomotor functioning and comorbid conditions) associated with different accuracy of self-awareness. The purpose was to recognize the characteristics of older drivers who can or cannot accurately modify their perception of driving ability according to their changes in actual driving performance over time.

Consistent with a study conducted in Australia, which also measured older drivers' changes in perceived driving ability and naturalistic driving performance over one year, findings in this study supported that older drivers' perceived driving ability generally remained stable within this time frame, while most older drivers' actual driving performance deteriorated (Koppel et al., 2017). Despite the existence of individual variance, in average, older drivers' lack of variability in the PDA scores across three years was also reported in Rapoport et al. (2016). However, they had worse driving performance over one year as measured using the eDOS. While Koppel et al. (2017) used error rates in total recorded maneuvers (i.e. intersection, lane change, merge, and low speed maneuver) to represent older drivers' performance in their everyday driving environment, our study adopted a weighted score to account for the number and the risk level of each driving error. Some driving errors may be more dangerous than others, depending on the type and the complexity of traffic condition where the error takes place. For example, selecting a narrow gap to make a left turn is more likely to cause a crash than committing a rolling stop with careful environment verification; not signaling in a quiet residential area is not as risky as the same error made at a right turn on busy boulevards. Compared to the error rates, the weighted score is suggested to better reflect the risk in naturalistic driving observations (Di Stefano & Macdonald, 2006). However, since both the error rates and the weighted score are not yet validated measures to determine one's fitness-to-drive, the decline observed in the participants could only indicate their worse driving performance over time, but not their changes in fitness-to-drive.

Neither Koppel et al. (2017) nor this study found a relationship between the changes in perceived and actual driving ability over one year, indicating many older drivers' perceived driving ability do not correspond to changes in their driving performance. However, Koppel et al. (2017) did not examine the differences in older drivers' self-awareness by dividing those who over-, accurately, or under-estimated their driving performance over time. To further investigate the characteristics of older drivers with different types of self-awareness, it is necessary to compare the correspondence between the perceived and actual driving ability.

This is the first study to categorize the accuracy of self-awareness of changes in driving ability. A majority of older drivers (45%) demonstrated stable or better perceived and actual driving ability over one year; this might be due to our sample, which included active, healthy drivers who drove frequently and had no severe neurological conditions. Another 40% of the participants had considerably worse driving performance at the second year. In this category, only one-fifth of them accurately detected their changes in driving ability and perceived themselves having worse driving ability over one year. This result indicates that many older drivers could not accurately monitor and appraise their own changes in driving performance. As several cross-sectional studies reported that over-estimation of driving ability is common among older drivers (38% to 53 %) (Broberg & Dukic Willstrand, 2014; Chen et al., 2018; Freund, Colgrove, Burke, & McLeod, 2005; Riendeau, Maxwell, Patterson, Weaver, & Bedard, 2016), this study suggested that it may be due to their insufficient self-monitoring skills to accurately estimate their changes in driving ability over time. At last, a small proportion (7%) of older drivers under-estimated their changes in driving performance: they perceived themselves as having much worse driving ability, whereas their actual driving performance was stable. This result may be related to the change in the PDA score. Participants' PDA ratings were very high at the first session: around 25% of them had their score greater than 40 (over its maximum score of 45). Also, the change of PDA score was negatively associated with the PDA score at the first session (i.e. higher PDA score at session 1 is related to greater decrease of the PDA score between the two sessions). This may suggest that these drivers who rated themselves very good at the first session become more modest at the second session, indicating a phenomenon of regression toward the mean (Portney & Watkins, 2009). The extreme high score of PDA at the first session tended to move closer to the group mean at the second session, leading to the drivers categorized into under-estimation of no change in driving ability. Nevertheless, we consider that the cut-off score of 4 points decrease in the PDA for categorizing older drivers with worse perceived driving ability over time was reasonable, as it presented the participants who had the PDA change below and over than one standard deviation in this sample and greater than 10% drop of the total score. It is possible that some older drivers' perceived driving ability became worse by other unmeasured reasons, such as some discussions related to their age and driving performance with families or doctors between the two sessions, which might change the view of their own perception of driving ability.

The four self-awareness groups did not differ in their demographic characteristics (i.e. age, gender, and educational level), clinical functioning (i.e. visual, cognitive, executive, psychomotor and comorbidity conditions) at the first session, or in their changes in clinical functioning over one year. While past studies found that older age and being female are associated with lower levels of driving comfort, worse perceived driving ability and more self-regulatory behaviors among older drivers (Gwyther & Holland, 2012; Tuokko et al., 2013), our study did not find the association of age and gender with self-awareness of changes in driving ability. Regardless of age and gender, older drivers could be accurate or inaccurate in their perceived driving ability comparing with their changes in naturalistic driving performance. In addition, since participants in this study were highly-educated, relatively healthy without any progressive neurological conditions, the unimpaired and modest changes in clinical functioning are likely to be comparable across different self-awareness groups.

The only exception that showed a marginal association with older drivers' self-awareness of changes in driving ability was the processing speed and executive functioning measured using the TMT-B at the first session. The order from the worse to the best performance in the TMT-B across groups was under-estimation of stable driving performance (group 3) < accurate estimation of no changes in driving performance (group 4) < accurate estimation of worse driving performance (group 1) and over-estimation of worse driving performance (group 2). Our last cross-sectional study demonstrated that under-estimation of driving ability is associated with worse processing speed and over-estimation of driving ability is related to better processing ability (Chen et al., 2018). This study builds on the previous research and demonstrated that using a longitudinal design, a similar relationship was shown between processing ability and self-awareness of changes in driving ability over time. It might seem counterintuitive that older drivers with worse driving performance in their naturalistic driving environment over one year, regardless of their changes in perceived driving ability, had better TMT performance than those who had stable or better driving performance, since worse TMT performance was found to be associated with having crash history (Daigneault, Joly, & Frigon, 2002) and failing a standard on-road driving test (Classen, Wang, Crizzle, Winter, & Lanford, 2013) among older drivers. However, studies using the Candrive database found that worse performance on the TMT-B is associated with lower perceived driving ability among community-dwelling older drivers, which may trigger the adoption of more strategic and tactical self-regulatory behaviors to drive more carefully in a less complex environment (Rapoport et al., 2016). Unlike the standard on-road driving evaluations, which includes fixed routes to ensure that the difficulty level of the test remains the same for all clients, the naturalistic driving observation, such as eDOS, enables older drivers to choose driving conditions and routes that are familiar and comfortable for them. As a result, worse PDA performance might lead to under-estimation of changes in driving ability in older adults' naturalistic driving environment. Despite this, we did not find differences in this study in the complexity of everyday driving routes chosen by each self-awareness group, it would be interesting to explore further about other strategic or tactical self-regulatory behaviors adopted in older adults' everyday driving between the awareness groups.

There are some limitations in this study. First, due to the strict rule of selecting participants with PDA questionnaire administered close to the day of the driving observation, a number of participants were excluded in the analysis. The small sample size, especially the low number of participants in two of the self-awareness groups (i.e. group 1 and 3), might have caused low statistical power and high probability to commit a Type II error. Some clinical factors might have been significantly different between groups with a larger sample size and power, such as the TMT-B. It will be encouraging to expand the sample size to examine the characteristics of different self-awareness groups.

Second, our study sample may be representative of the common older drivers in North America. Using convenience sampling and excluding older drivers with neurological conditions, our study participants were fairly healthy, active, and highly-educated. Also, they might be more aware of their changes in the driving-related abilities as they underwent comprehensive driving-related functional assessments each year for the Candrive study.

At last, some participants' PDA scores and all of their clinical functioning data were retrieved from Candrive annual assessments. Changes in these factors could have happened within the interval between the Candrive assessment and the driving observation. However, criteria had been set to exclude Candrive assessments administered too far from the driving observation. The range to determine the data inclusion/exclusion was based on a research that found the clinical factors remained stable within one year (Smith et al., 2013).

The accuracy of self-awareness is one factor proposed to influence older adults driving safety and performance, but this study found that many older drivers are inaccurate in self-awareness of changes in driving ability over time. Future research will be needed to examine how accuracy of self-awareness of driving ability influences older drivers' driving performance and safety. One question would be if older drivers who under-estimated their changes in driving performance reduce their driving frequency and distance at a faster pace or quit driving earlier than older drivers with accurate and over-estimation of driving ability. Or, if drivers who over-estimated their driving ability have more prospective/retrospective crashes compared with those who can accurately monitor and appraise their driving ability. It might also be important for clinicians to address earlier in older adults' self-awareness of driving ability in retraining or refreshing programs by educating them about the impacts of changes in functional abilities on driving ability and potential self-regulation strategies.

6.7 Conclusion

Many older drivers cannot accurately monitor their changes in driving ability over time. For those who do not detect changes in declining driving performance, the over-estimation of driving ability could lead to higher driving risk exposure; others may be over-cautious about their changes in driving ability and over limit their driving or quit driving prematurely.

We did not find that the accuracy of self-awareness of changes in driving ability is related to older drivers' age, gender, educational level, driving-related functioning at the initial evaluation session or changes in driving-related functioning over time. Between groups with different accuracy of self-awareness, only the processing speed and executive function measured using the TMT-B reached a marginal significance. Older drivers who under-estimated their changes in driving ability (while there was no considerable decline over time) had worse TMT-B performance than those who accurately and over-estimated their worse driving performance over time. Future research will be needed to expand the sample size and to examine the association of self-awareness of driving ability and driving safety.

6.8 References

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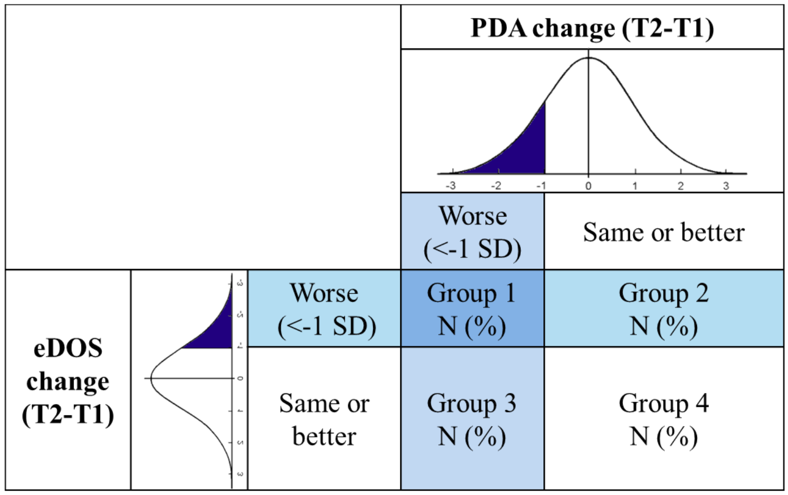

Figure 6.1: Categorization of older drivers' accuracy of self-awareness of changes in driving ability.

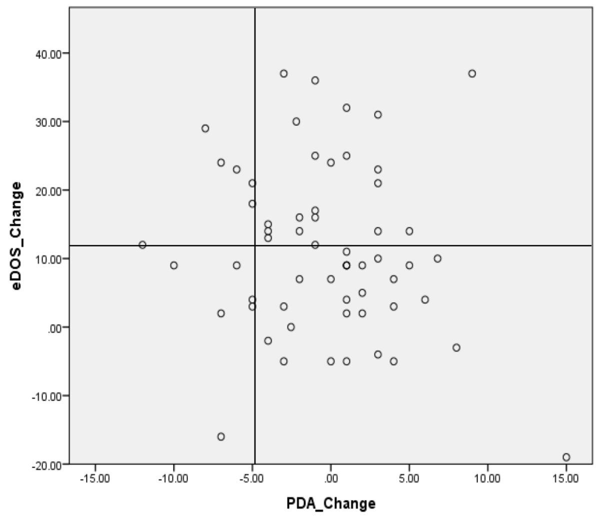

Figure 6.2: Distribution of PDA and eDOS change scores. The vertical and the horizontal lines are the cut-offs for discriminating participants with worse perceived and actual driving ability.

Table 6.1: Participants' performance on eDOS, PDA, and complexity of eDOS driving route at session 1, session 2, and changes over one year

	Session 1 (S1)				Session 2 (S2)			Change (S2-S1)		Paired t-test	
	n	Mean (SD)	Range	IQR	Mean (SD)	Range	IQR	Mean (SD)	Range	t	*p*
PDA	60	35.7 (6.1)	21-45	31 to 41	35.3 (5.4)	24-45	32-39	-0.3 (4.8)	-12 to 15	0.6	0.5
eDOS	60	8.8 (7.6)	0-30	3 to 12.8	20.1 (11.6)	3-44	10-29.3	11.3 (12.3)	-19 to 37	-7.1	<.001*
eDOS maneuver/environment complexity	60	1.7 (0.3)	1.0-2.4	1.5 to 1.9	1.7 (0.2)	1.3-2.5	1.5-1.9	0.0 (0.2)	-0.3 to 0.8	-1.3	0.2

PDA: Perceived Driving Ability; eDOS: electronic Driving Observation Schedule.

IQR: Inter-quartile range.

Table 6.2: Participants' performance on clinical functional assessments and changes over one year

	Session 1 (S1)			Session 2 (S2)			Change (S2-S1)			Paired t-test	
	n	Mean (SD)	Range	n	Mean (SD)	Range	n	Mean (SD)	Range	t	*p*
Snellen test	60	0.8 (0.3)	0.5-1.54	55	0.8 (0.3)	0.4-1.54	55	0.0 (0.3)	-0.67 to 0.83	-0.3	0.8
Contrast sensitivity	56	1.9 (0.1)	1.35-2.25	50	1.9 (0.1)	1.50-1.95	50	0.0 (0.1)	-0.30 to 0.30	0.9	0.4
MoCA	60	26.8 (2.4)	19-30	55	26.2 (2.2)	20-30	55	-0.7 (2.3)	-8 to 5	2.2	0.03*
MVPT-3	60	11.2 (1.9)	5-13	55	11.2 (1.6)	7-13	55	-0.1 (1.5)	-3 to 4	0.3	0.8
TMT-A	60	41.2 (13.9)	4-76	54	41.7 (11.8)	24-70	54	-0.5 (9.6)	-26 to 31	0.4	0.7
TMT-B	59	96.1 (45.7)	43-309	53	102.3 (58.8)	11-348	53	4.2 (59.9)	-187 to 211	-0.5	0.6
TUG	59	10.4 (2.9)	6-25	50	10.6 (3.0)	6-22	50	0.4 (1.9)	-3 to 5	-1.4	0.2
mCIRS: number	60	9.9 (5.2)	2-23	56	10.3 (5.3)	2-24	56	0.2 (1.9)	-5 to 6	-0.8	0.4
mCIRS: severity	60	13.7 (7.3)	3-32	56	14.3 (7.2)	2-34	56	0.3 (2.9)	-7 to 8	-0.9	0.4

MoCA: Montreal Cognitive Assessment; MVPT-3: Motor-Free Visual Perception Test version 3 (visual closure); TMT: Trail Making Test; TUG: Timed-up and go test; mCIRS: modified Cumulative Illness Rating Scale.

*$p<0.05$

Table 6.3: Number and percentage of participants within each group of accuracy of self-awareness of changes in driving ability

		PDA change		
		Worse	Same or better	Total
	Worse	Gr 1: 5 (8.3%)	Gr 2: 20 (33.3%)	25 (41.7%)
eDOS change	Same or better	Gr 3: 7 (11.7%)	Gr 4: 28 (44.7%)	35 (58.3%)
	Total	12 (20%)	48 (80.0%)	60 (100.0%)

eDOS, electronic Driving Observation Schedule; PDA, Perceived Driving Ability

Table 6.4: Mean (SD) of clinical functioning at the first session between the four awareness groups

Group	n	Snellen	MoCA	MVPT-3	TMT-A	TMT-B	TUG	mCIRS: number	mCIRS: severity
1	5	10.5(2.7)	27.2(2.0)	10.6(2.1)	36.8(4.3)	85.4(14.5)	12.4(2.9)	10.8(6.1)	16.2(9.2)
2	20	12.9(4.2)	26.9(2.9)	11.0(2.1)	40.0(14.4)	80.4(27.6)	10.0(4.2)	9.4(5.0)	13.4(6.7)
3	7	12.4(5.9)	26.0(2.0)	11.0(1.6)	50.0(14.8)	132.7(50.5)	10.6(2.1)	9.6(5.5)	12.6(6.0)
4	28	14.9(4.0)	26.9(2.4)	11.4(1.7)	50.7(14.1)	100.2(53.9)	10.3(1.8)	10.2(5.3)	13.9(7.8)
F		2.13	0.32	0.27	1.18	2.27	0.96	0.14	0.26
p		0.11	0.81	0.85	0.33	0.06	0.42	0.93	0.85

Group 1: accurate estimation of worse driving performance; Group 2: over-estimation of worse driving performance; Group 3: under-estimation of stable driving performance; Group 4: accurate estimation of no changes in driving performance

PDA: Perceived Driving Ability; eDOS: electronic Driving Observation Schedule; MoCA: Montreal Cognitive Assessment; MVPT-3: Motor-Free Visual Perception Test version 3 (visual closure); TMT: Trail Making Test; TUG: Timed-up and go test; mCIRS: modified Cumulative Illness Rating Scale.

Table 6.5: Mean (SD) change in clinical functioning over one year between the four awareness groups (session 2 - session 1)

Group	n	Snellen	MoCA	MVPT-3	TMT- A	TMT-B	TUG	mCIRS: number	mCIRS: severity
1	4	.6(2.4)	-2.3(2.6)	.3(3.0)	.0(6.0)	19.5(3.7)	1.0(2.5)	-.3(2.2)	-.3(2.7)
2	19	.6(4.0)	-1.0(2.9)	.1(1.5)	-3.1(10.9)	-.4(15.9)	.9(1.9)	.4(2.2)	.7(3.4)
3	6	-.8(7.3)	-.7(1.6)	-.2(1.2)	-2.3(5.5)	.8(68.8)	.3(2.0)	.8(1.5)	1.2(1.3)
4	27	.0(4.6)	-.23(1.8)	-.2(1.3)	1.9(9.6)	6.0(82.6)	-.2(1.7)	.0(1.7)	.0(2.9)
F		0.16	0.97	0.20	1.05	0.13	1.35	0.45	0.42
p		0.92	0.41	0.89	0.38	0.94	0.27	0.72	0.74

Group 1: accurate estimation of worse driving performance; Group 2: over-estimation of worse driving performance; Group 3: under-estimation of stable driving performance; Group 4: accurate estimation of no changes in driving performance

PDA: Perceived Driving Ability; eDOS: electronic Driving Observation Schedule; MoCA: Montreal Cognitive Assessment; MVPT-3: Motor-Free Visual Perception Test version 3 (visual closure); TMT: Trail Making Test; TUG: Timed-up and go test; mCIRS: modified Cumulative Illness Rating Scale

CHAPTER 7: DISCUSSION

7.1 SUMMARY OF FINDINGS

The overall purpose of this doctoral thesis was to contribute evidence toward older drivers' self-awareness of their driving ability in their naturalistic driving environment. The main findings of each study conducted to meet this aim are summarized.

7.1.1 Manuscript #1 (Chapter 3)

This manuscript is a reflective literature review comparing how two different on-road driving evaluation approaches, the standard on-road driving evaluation (SODE) and the naturalistic driving observation (NDO), influence older adults' driving performance. The theoretical analysis contrasted the strengths and limitations of each approach and suggested factors to be considered when selecting a measurement tool for determining older drivers' driving ability.

The two approaches were described in detail and compared using the Occupatioanl Therapy Person-Environment-Occupation (PEO) model (Law et al., 1996) and Michon's model of driving (Michon, 1985). Briefly, the SODE is a structured evaluation that asks clients to drive a dual-brake vehicle on pre-determined routes following a driving instructor's directives, while during the NDO, clients are required to drive their own car from home to their selected destinations on routes familiar to them. Both approaches record the client's behavior and performance in a systematic manner.

The most important difference between the two approaches is how the dynamic interactions between person, occupation, and environment factors impact a driver's performance. During the SODE, the driving maneuver and environment is controlled and fixed; clients' performance is an indicator of their driving capacity in the structured condition. Performances on the SODE are comparable between drivers (e.g. discriminating safe and at-risk drivers based on their driving ability) and across sessions (e.g. monitoring changes in one's driving ability over time). In contrast, during the NDO, a driver can choose the maneuvers and driving environments that they feel comfortable and familiar with. Performance during the NDO is adjusted by the driver's self-awareness of their driving ability and behavior modifications. For older drivers, even though their driving capacity may have declined, choosing to avoid difficult and complex driving conditions could help them maintain a stable driving performance. The NDO is a tool that can reveal a driver's everyday performance in their naturalistic environment, including their accuracy of self-awareness of driving ability and their capacity to modify their driving behaviors.

One challenge of the NDO approach is that its scoring method has not been fully developed to take into consideration the differences in driving maneuvers and environments: while some drivers may drive on complex routes with more traffic or higher speed limits, others may only drive on quiet streets or straight service roads. The comparison of driving performance in different conditions between clients or across observation sessions is problematic. Creating a score to represent the complexity of driving maneuvers and environments was necessary to improve the interpretation of NDO driving performances by disentangling the factor of route complexity.

7.1.2 Chapter 4

In this thesis, older adults' driving performance was measured using a novel NDO approach, the electronic Driving Observation Schedule (eDOS), to examine their self-awareness of driving ability in their everyday driving environment. The study in this chapter aimed to develop two different scoring systems for the eDOS tool. The first was the driving maneuver/environmental complexity score. This score addresses the limitation mentioned in the first manuscript to identify the relationship between older drivers' NDO performance and their choice of route complexity. Also, it can be used to control for the differences in the complexity of driving maneuver/environment and allows for comparisons of driving performance between drivers and across sessions.

The second score was the weighted eDOS total score. The original eDOS total score was calculated by the percentage of appropriate maneuvers over the total number of maneuvers performed, which did not take into consideration the different risk levels of each type of driving error in their corresponding environment. A weighted eDOS score was needed to improve the scoring by accounting for the risk level of each driving error.

To generate the two scores for the eDOS, experts in the field of driving rehabilitation were consulted using a two-round on-line survey. Thirteen experts completed the first survey, and 10 of them completed the second survey. Using maneuver types (e.g. driving maneuver at intersections, lane change, and merging) and environmental descriptors (e.g. traffic sign, speed zone, and number of lanes) recorded on the eDOS scoring sheet, the complexity of the driving maneuver/environment was classified into five hierarchical categories. The classification system of the driving maneuver/environmental complexity is presented in Table 4.4. The risk levels of 13 types of driving errors made in each driving complexity category were rated on a 3-point Likert scale (1 = low risk, 2 = moderate risk, and 3 = high risk). Results of the error weighting are presented in Table 4.5.

The primary investigators created the formula for the driving maneuver/environmental complexity score based on the classification system. This score ranges from 1 to 3; higher scores indicate more complex driving maneuvers and environments during the eDOS drive. The weighted eDOS total score is generated by the sum of the weighted driving errors; a lower weighted eDOS score indicates better driving performance, while higher scores indicate that the driver either committed some severe errors (e.g. choosing an unsafe gap during a lane change on a boulevard) or demonstrated several bad driving habits (e.g. no signalling on quiet residential streets for a right turn). The two scores were approved by other researchers who developed or had experience using the eDOS.

7.1.3 Manuscript #2 (Chapter 5)

This manuscript presents a cross-sectional study examining older drivers' accuracy of self-awareness of driving ability and its associated factors. Their accuracy of self-awareness is determined by the correspondence between perceived driving ability (measured by the Perceived Driving Ability [PDA] Questionnaire) and actual driving performance (represented by the weighted eDOS total score). Older drivers were categorized into under-, accurate, and over-estimation groups. The association between older drivers' demographic information (i.e. age, gender, and educational level) and clinical factors (i.e. visual, cognitive, psychomotor and executive functioning, mood, comorbid medical conditions) with their accuracy of self-awareness of driving ability were examined.

This study was built on the infrastructure of the Candrive longitudinal study. Eligible older drivers were recruited from three Candrive research sites: Montreal, Ottawa, and Hamilton. Data from 108 participants (age: Mean=80.6 years, SD=4.9; male: 67.6%) who met the inclusion criteria were analyzed.

The main findings of this manuscript were: 1) most older drivers over-estimated their driving ability. The proportion of over-estimation, accurate estimation, and under-estimation was 52%, 29%, and 19%, respectively; 2) using an ordinal regression model, it was found that older drivers' visuo-motor processing speed (measured using the Trail Making Test) and number of self-reported comorbid medical conditions (measured by the modified Cumulative Illness Rating Scale) are significantly associated with accuracy of self-awareness of driving ability. Older drivers who over-estimated their driving ability had better visuo-motor processing speed and fewer self-reported comorbid medical conditions, while those who under-estimated their driving ability had worse visuo-motor processing speed and more comorbid medical conditions.

7.1.4 Manuscript #3 (Chapter 6)

Expanding from the previous study, this manuscript focused on older drivers' self-awareness of their changes in driving ability over time; a construct that had never been studied before. For older drivers undergoing a normal aging process, changes in driving ability and performance over time could be gradual and difficult to detect. Knowing the demographic and clinical characteristics of older drivers who can or cannot detect their changes in driving ability over time is important for clinicians to identify older drivers who may benefit from a driving retraining program. Such programs can help clients learn how to better monitor their driving ability and adjust their driving behaviors early on to remain safe on the road for as long as possible.

Sixty older adults' (age: Mean=80.3 years at the first session, SD=5.5; male: 70%) perceived (measured using the PDA questionnaire) and actual driving performance (measured using the eDOS) was evaluated twice over one year, and their demographic information and changes in clinical functional abilities were retrieved from the Candrive annual assessments. Self-awareness of changes in driving ability was determined by the correspondence between changes in perceived and actual driving ability. Differences in demographic and clinical factors among different accuracy levels of self-awareness were examined.

The results showed that nearly half of the participants had stable perceived and actual driving ability over one year, one-third could not detect their worse driving performance and over-estimated their driving ability, and the remaining participants either accurately detected their worse driving performance (8%) or under-estimated their stable driving performance (12%).

None of the measured demographic or clinical factors were associated with the older drivers' self-awareness of changes in driving ability over time, except that mental processing and executive functioning (measured using the Trail Making Test at the first session) showed a marginal effect ($p=0.06$). The older drivers who under-estimated their changes in driving performance had the worst performance in processing speed and executive function, followed by the stable group; participants who had worse driving performance at the second session, regardless of their perceived changes in driving ability, had faster processing speed and better executive functioning.

7.2 INTERPRETATION OF STUDY FINDINGS

Studies completed in manuscripts #2 and #3 were the first examining older drivers' self-awareness of driving ability in their everyday driving environment by comparing the correspondence between perceived driving ability with their driving performance in a naturalistic environment. Differences in demographic and driving-related clinical factors between different self-awareness groups (under-, accurate, and over-estimation groups) were examined. To avoid repetition of the discussion points mentioned in the manuscripts, the following section will focus on the interpretation of the results and study limitations that were not in detail addressed before. The discussion will first address the unique contribution of the thesis. This will be followed by a comparison of the study findings with past studies in terms of the measurement of older drivers' perceived and actual driving ability, and then by the factors associated with self-awareness of driving ability.

7.2.1. Older drivers' perceived driving ability

The Perceived Driving Ability (PDA) questionnaire was administered to evaluate older drivers' perception of their current driving ability. This questionnaire was selected because it was co-designed and validated with older drivers; the items include several driving situations reflective of older adults' driving ability; and its rating scale directly asks clients to rate their driving ability without comparing with others. This approach to measuring perceived driving ability is more likely to prompt deeper reflection on one's driving ability and reduce the biased, inflated positive self-ratings due to social comparison (i.e. asking clients to rate their driving ability in comparison to others) as was done in many earlier studies (Blanchard & Myers, 2010; MacDonald, Myers, & Blanchard, 2008).

In manuscript #2, older drivers' perceived driving ability was categorized into low, medium, and high using two cut-off scores. The maximum PDA score is 45; the cut-off scores were 29 (16^{th} percentile of the study sample) and 35 (50^{th} percentile of the study sample). A PDA total score equal to or lower than 29 indicates that the average rating is lower than "good" (the rating scale for the 15 PDA questions is 0=poor, 1=fair, 2=good, and 3=very good). Compared with previous literature, the proportion of participants with low perceived driving ability was higher in our study (16% vs. 0-8% defined by a bit worse than the other drivers or having poor to fair driving ability) (Freund et al., 2005; Marottoli & Richardson, 1998; Riendeau et al., 2016; Selander et al., 2011). The detailed questions included in the PDA might have triggered participants to self-reflect more deeply on their driving ability than the general question used in previous research, leading to a somewhat lower self-rating (MacDonald et al., 2008; Toglia & Kirk, 2000). On the other hand, a PDA score higher than 35 indicates that a driver rated his/her driving ability over 75% fully competent (calculated by 35/45*100%=78%). This score categorized one half of the study sample as having high perceived driving ability, which is more conservative than past studies that reported 68%-76% of healthy older drivers rated their driving ability better than the others (Freund et al., 2005; Marottoli & Richardson, 1998; Selander et al., 2011; Wood et al., 2013).

Findings from manuscript #3 showed that older drivers' perceived driving ability remained stable over one year; the average PDA score changed from 35.7 at session one to 35.3 at session two, one year later. This result is consistent with past findings (Koppel et al., 2017; Rapoport et al., 2016). Furthermore, this study focused on the individual variation of perceived driving ability over time for the purpose of examining older drivers' self-awareness of changes in driving ability. The PDA change score below one standard deviation (i.e. 4.8 points) was used to indicate that a driver perceived his/her driving ability worsened over one year (20% of our sample), otherwise, their driving ability was perceived as stable or improved (80% of our sample). As this is the first study to categorize older drivers' changes in perceived driving ability over time, it is not known whether these values are similar to other samples.

7.2.2 Older drivers' actual driving ability

In this study, older drivers' actual driving ability was measured using the eDOS. This is a reliable and validated tool designed to observe and record older drivers' naturalistic driving behavior in familiar areas around their home (Vlahodimitrakou et al., 2013). Older drivers' choice of route was found to be representative of their everyday driving trips measured by the GPS data tracking and recording their driving for approximately 3 months (Smith et al., 2012). Most older drivers reported that their driving performance during the eDOS was about the same as their everyday driving (97%), and that they were at ease (27%) or completely at ease (73%) while being observed during the eDOS drive (Koppel et al., 2013; Koppel et al., 2016).

To examine the accuracy of older drivers' perceived driving ability, previous studies adopted different approaches to assessing driving ability, including the SODE (Brown et al., 2005; Freund et al., 2005; Hunt et al., 1993; Marottoli & Richardson, 1998; Okonkwo et al., 2009; Riendeau et al., 2016; Selander et al., 2011; Wild & Cotrell, 2003; Wood et al., 2013), on-road driving evaluations in clients' familiar areas in a dual-brake vehicle on guided routes (Broberg et al., 2014), driving simulation tests (Freund et al., 2005), and crash history (Marattoli & Richardson, 1998). Compared to these approaches, the eDOS assesses older drivers' driving ability in a more ecological environment by asking them to drive their own car on their everyday driving routes from home. During this type of naturalistic driving observation mental stress and anxiety is low (Bhalla, Papandonatos, Stern, & Ott, 2007; Fairclough, Tattersall, & Houston, 2006; Lundberg & Hakamies-Blomqvist, 2003; Uc et al., 2009) and they are free from the additional mental workload required for adapting to a new vehicle or a driving simulator (Berndt, May, & Clark, 2006; Engstrum, Johansson, & Ostlund, 2005; Sinar, Meir, & Ben-Shoham, 1998). Also, participants are allowed to demonstrate secondary tasks during the drive (e.g. chatting with passengers, talking with co-pilots for navigation or receiving warnings about potential risks), as well as strategic and tactical self-regulatory driving behaviors (e.g. driving on routes with less complex conditions or lower speed limits). The eDOS is a novel and unique objective approach representing everyday driving performance and is appropriate for comparing how accurately older drivers perceive their driving ability.

In addition, the study presented in Chapter 4 made a notable contribution to the use of the eDOS. The weighted eDOS score was created to account for varying risk levels for each driving error. Compared to the original eDOS total score that treats all driving errors as equal (Vlahodimitrakou et al., 2013; Koppel et al., 2016, 2017), this new score assigns greater weights to driving errors with higher risk levels and no additional weight to habitual errors that are commonly made among experienced drivers. The weighted eDOS score can better represent older drivers on-road driving performance by considering the risk levels of their driving errors. Also, to our knowledge, the complexity of the driving maneuver/environment score is the first attempt to systematically quantify the complexity or difficulty level of the driving course for a NDO protocol. Some published SODE protocols have identified the complexity of their designed driving routes using the "zone" (e.g. parking lot, residential, suburban, highway, and city/downtown), traffic flow, and speed limits, as well as noted the number of controlled or uncontrolled turns made during the drive (Kay, Bundy, Clemson, & Jolly, 2008; Classen et al., 2017). However, during the eDOS, clients select their own driving routes near their home, and the complexity of their driving maneuver/environment can vary substantially. By reviewing past SODE protocols, consulting experts in driving rehabilitation, and verifying the recordings on the eDOS scoring sheet, a formula was created to calculate the level of complexity of the overall driving maneuvers and environment during the eDOS. This score can be used to control for the differences in driving routes while comparing the eDOS performance between clients or across observation sessions.

7.2.3 Older drivers' self-awareness of driving ability and changes in driving ability

One's self-awareness was determined by the concordance between perceived and actual driving ability. To accurately measure self-awareness, the tools used to assess both perceived and actual ability should focus on the same object and be comparable with each other (Myers, Paradis, & Blanchard, 2008; Sundström, 2008). The tools used in this thesis, the PDA for rating current ability on several driving conditions and maneuvers that are commonly encountered and problematic for them (Macdonald et al., 2008) and the eDOS designed to observe and record older adults' driving performance in their everyday driving environment (Vlahodimitrakou et al., 2013), are comparable in that they both assess the same target clientele (i.e. older drivers with typical aging), the same concept (i.e. driving ability), and in corresponding contexts (i.e. everyday driving environment). Using these two measures, the measurement of older drivers' self-awareness of driving ability is tenable. Past studies examined older drivers' self-ratings of their general, everyday driving ability but administered driving evaluations under structured, unfamiliar driving contexts (Broberg & Dukic Willstrand, 2014; Brown et al., 2005; Freund et al., 2005; Hunt, Morris, Edwards, & Wilson, 1993; Marottoli & Richardson, 1998; Okonkwo et al., 2009; Riendeau, Maxwell, Patterson, Weaver, & Bedard, 2016; Selander et al., 2011; Wild & Cotrell, 2003; Wood, Lacherez, & Anstey, 2013), and therefore the correspondence between the context for perceived and actual driving may differ.

Two studies used the PDA and the eDOS to examine the association between older drivers' perceived and actual driving ability in their everyday driving environment (Koppel et al., 2016, 2017), but the study findings are inconsistent. In contrast to these studies that attempted to find a linear relationship between the perceived and actual driving ability, studies in this thesis divided older drivers into over-, accurate, and under-estimating groups using the concordance between the PDA and the eDOS scores. This method did not assume that a linear relationship would be found between the PDA and the eDOS score (i.e. poorer driving performance is related to having perceived worse driving ability). Most importantly, older drivers with inaccurate self-awareness of driving ability are more likely to have difficulties with their everyday driving safety and performance, and therefore, should be identified. The characteristics and driving-related issues of those who under-estimated and over-estimated their driving ability is likely not the same, so it is important to separate these two groups with inaccurate self-awareness. The methodology applied in this study will provide clinicians and researchers a better understanding of the topic of older drivers' self-awareness.

The study presented in Manuscript #3 that examined self-awareness of changes in driving ability over one year was also an important and novel contribution to the topic of older drivers' self-awareness. No past studies identified older drivers who over-, accurately, and under-estimated their changes in driving ability over time. While it was found that approximately half of the older drivers had the same or better perceived and actual driving ability over one year, the other one-third of them who could not detect their declining driving ability would be of greater concern for their driving safety.

7.2.4 Associated factors related to self-awareness of driving ability

Our studies examined the association between demographic and driving-related functional ability with older drivers' self-awareness of driving ability. Findings indicated that better visuo-motor processing speed, better executive functioning, and fewer comorbid medical conditions were associated with over-estimation of driving ability or changes in their driving ability over one year. These findings are novel and are incongruent with past results on older drivers' self-awareness. Wood et al. (2013) reported that worse cognitive functioning and executive functioning is related to over-estimation of driving ability, and two other studies did not find any relationship between cognitive functioning and older drivers' self-awareness of driving ability (Broberg & Dukic Willstrand, 2014; Freund et al., 2005). These differences may be attributed to the different assessment tools used to measure older drivers' self-awareness of driving ability (i.e. general questions vs. the PDA questionnaire; the SODE or driving simulation test vs. the eDOS). In this study, it was found that poorer processing speed and executive functioning (measured using the Trail Making Test [TMT]) is associated with having perceived worse driving ability (measured using the PDA) (Rapoport et al., 2013, 2016) and worse driving performance in the SODE (Mathias & Lucas, 2009), but not with eDOS performance (Koppel et al., 2016, 2017). For community-dwelling older drivers, lower perceived driving ability triggers more self-regulatory behaviors (Blanchard & Myers, 2010; Charlton et al., 2006; Jouk et al., 2014; Meng & Siren, 2012; Molnar et al., 2014), which can only be demonstrated during a NDO approach (e.g. the eDOS). It may be that the modification of driving behaviors adopted by those who perceived themselves as having poor driving ability (related to poorer performance in processing speed and executive functioning) had helped them to maintain good driving performance. On the contrary, those who over-estimated their driving ability were more likely to have better processing ability and executive functioning; they rated themselves as having good driving ability but drove less carefully and made more errors in their naturalistic driving environment.

In addition, it was not found that older drivers' self-awareness of driving ability or changes in driving ability is associated with any of the measured demographic characteristics (i.e. age, gender, and educational level) or other clinical factors (i.e. visual acuity, contrast sensitivity, general cognitive functioning). Although some of the factors are associated with adopting self-regulatory behaviors, such as older age, female gender (Chalrton et al., 2006; D'ambrosio, Donorfio, Coughlin, Mohyde, & Meyer, 2008; Kostyniuk & Molnar, 2008; Molnar et al., 2014; Sargent-Cox, Windsor, Walker, & Anstey, 2011), and worse contrast sensitivity (Molnar et al., 2014), our study did not show that these factors are related to accuracy of self-awareness of driving ability in an everyday driving environment.

7.3 STUDY LIMITATIONS

Several study limitations were recognized, and their corresponding statements of explanation or future directions were specified in Chapter 4, Manuscript #2 and Manuscript #3. A brief summary is provided here: i) in Chapter 4, the weighted eDOS total score was designed to be rated on an ordinal scale, rather than a ratio scale. The weights provided in the scale for each error may not be accurate when presenting the relative risk levels (i.e. committing one high-risk error cannot be assumed to be equal to committing three low-risk errors). Future studies will be needed to validate the weighting scales for the eDOS score to accurately discriminate low and high-risk older drivers. ii) In Manuscript #2 and #3, some of the participants' PDA scores and all the participants' clinical functioning data were retrieved from the Candrive annual assessments. Participants' condition could have been changed within the interval between the Candrive annual assessment and their eDOS observation. Nevertheless, some exclusion criteria were applied to eliminate data that were collected too far from the driving observation; the acceptable interval was based on a study that found older drivers' functional abilities were stable within the defined range (Smith et al., 2013). iii) Participants in the Candrive and the eDOS observation studies were recruited by convenience sampling, and were fairly healthy, active, and highly-educated (Koppel et al., 2016; Rapoport et al., 2016). Also, all of them had undergone the Candrive annual assessments for at least four years before the eDOS driving observation study launched in 2013 and most of them continued their annual driving assessments during and after the two eDOS observations. Completing these driving-related assessments may have led them to have more opportunities to reflect on their driving ability and behaviors that may impact their driving safety and increase their self-awareness of their driving ability. Therefore, results found in this thesis may not be generalizable to all drivers in this age group. iv) The sample size in Manuscript #3 was small and might lead to low statistical power and higher probability of committing a Type II error (Portney & Watkins, 2009). Future studies will be needed to expand the sample size to have sufficient statistical power to examine the characteristics of the different self-awareness groups.

Other study limitations that have not been included in previous chapters are described here. First, compared to the original version of the eDOS (see Appendix 3.1), some procedures have been modified in the eDOS evaluation used in this study. Differences in these two versions are worth noting to better interpret the results and acknowledge study limitations. The main difference is that the original eDOS has the observers sitting in the rear passenger seat in the participants' vehicle, while in the modified version, observers record their driving behavior while in a following car. This change was decided to ensure observers' safety on the road. However, in the modified eDOS, observers cannot see the drivers' head or eye movement from the following car. Therefore, in the studies of manuscript #2 and #3, the error type of "observation of road environment", including "no mirror use" and "no looking", were not recorded or analyzed. Lack of sufficient environment observation is one of the most important driving errors to identify at-risk older drivers (Kay et al., 2008) and missing this error type recorded in the modified eDOS is a potentially important limitation. For future research, it would be recommended to install cameras in the drivers' car to capture their head and eye movements, hand positioning, secondary tasks (e.g. changing radio channels), and driving environment during the eDOS. The video clips will be able to identify the drivers' in-car behaviors and improve the used of the modified eDOS.

Another limitation of the modified eDOS is that older drivers might be aware of the observers' car following behind and may have changed their driving behavior compared to their everyday conduct (e.g. checking the rear mirror more frequently, finding a larger gap for the two vehicles to fit for lane changes, or pulling their car to the curb for the observers' car to catch up). Focus on the following car may influence the ecological validity of the eDOS, however, to decrease the impact of this potential problem, participants' were asked to drive as usual and were told that the observers would meet them at the predetermined destinations

The other study limitation addresses the comparability between the PDA and the eDOS. Although the two tools both conceptually evaluate older drivers' driving ability in a naturalistic driving environment, the detailed items included in the two tools do not perfectly match with each other. For example, three questions on the PDA questionnaire ask older adults' about their perceived ability to drive at night and one question asks about their ability to get in and out of the car, but these conditions were not observed or recorded during the eDOS. Lack of a perfect correspondence between the two tools could have limited the construct validity of this outcome variable to examine the accuracy of older drivers' self-awareness. Future research of this topic should consider the match between the evaluation tools used for assessing perceived and actual driving ability.

7.4 FUTURE DIRECTIONS

Results from studies included in this thesis have contributed valuable knowledge to our understanding of older drivers' self-awareness of driving ability in their naturalistic driving environment. In the future, several studies could help expand our knowledge about the influence of self-awareness on older adults' driving performance and safety.

First, for the measurement of naturalistic driving behavior, the eDOS tool represents an ecologically valid measure but it would be interesting to add the video data to be able to examine more comprehensively older drivers' in-car driving behavior, including their head and eye movements for environmental observation and their hand positioning. As mentioned previously, these driving behaviors are important to discriminate at-risk older drivers and adding this information would improve the eDOS validity. Also, using video during the eDOS observation would allow the recording of their involvement in secondary tasks (e.g. eating, grooming, talking with passengers or on hands-free phone, using the navigation system or car control panel) and may explore older drivers' self-awareness of driving ability when involved in secondary tasks (Prat et al., 2015). Engaging or not in a secondary task could reflect an older driver's self-awareness and self-regulatory behaviors (e.g., discard a distracting secondary task while driving in a challenging condition), and may be a moderating factor in lowering an older driver's crash risk (Charlton et al., 2013). For example, the interaction of an older driver and their co-pilot can help them to navigate in an unfamiliar area and reach destinations (Vrkljan & Polgar, 2007). In this era when vehicle technologies are developing and growing at an exponential rate, older drivers' self-awareness of using these novel car technologies will also be an interesting and important topic to explore.

Second, it was assumed that the accuracy of self-awareness of driving ability influences older adults' driving safety, however, this relationship was not examined in these studies. Future research will be needed to address this topic by investigating if older drivers who under-estimate their driving ability or changes in driving ability reduce driving frequency and distance at a faster rate or quit driving earlier than older drivers with accurate or who over-estimate their driving ability.

Third, it is recommended to expand the studies in this thesis to drivers in different age groups or to those with medical conditions and disabilities. For example, middle-aged drivers represent a group of drivers with the lowest crash rates (Cicchion & McCartt, 2014) and drivers with cognitive or visual impairments are typically referred to as "at-risk drivers" with higher probability of crash (Huisingh et al., 2017; Olsen, Taylor, & Thomas ,2014). The eDOS driving performance could be examined and used to validate the weighting scale for the eDOS score using the known groups method. This could help provide more appropriate weights on specific driving errors that could accurately discriminate drivers with higher crash risks. Also, using the same research paradigm to measure different groups of drivers' self-awareness of driving ability, studies can be conducted to determine whether older drivers with typical aging are more accurate or more inaccurate in their self-awareness than drivers with different levels of driving safety.

Finally, to gain better statistical power and greater confidence in the findings in Manuscript #3, a larger sample size and longer follow-up period is needed to address the issue of older drivers' self-awareness of changes in driving ability over time and its associated demographic and clinical factors.

7.5 CLINICAL IMPLICATIONS

Keeping older adults driving safer and longer is the prevailing approach to balance their individual needs for outdoor mobility through driving and the public's safety. This study found that many older drivers over-estimated their driving ability and changes in driving ability over time, while a small proportion of older drivers under-estimated their abilities. Drivers who over-estimated their driving ability may be at higher risk of crash, and those who under-estimated their driving ability may decide to prematurely stop or limit driving before they are unfit to drive.

Although self-awareness of driving ability was suggested as a factor that influences older adults' everyday driving safety, not many driving rehabilitation programs have integrated the assessment of self-awareness into their clinical practice or conducted training programs to enhance older drivers' self-awareness of driving ability (Eby et al., 2003; Horrey et al., 2015; Molnar et al., 2010). The study paradigm applied in this thesis--comparing the concordance between older drivers' perceived driving ability (measured using the PDA) and actual driving ability (measured using the eDOS)—would be a clinically feasible and ecologically valid method recommended to measure older drivers' self-awareness of driving ability in their everyday driving environment. During the NDO, not only do older drivers experience less stress and anxiety, and do not face any extra mental workload associated with adapting to an unfamiliar vehicle and driving conditions, it could also allow older drivers' to demonstrate their self-awareness and self-regulatory behaviors for clinicians to gain insight about their everyday driving behavior and environments.

The findings in this thesis can help clinicians consider how they might tailor their evaluation process, educational programs, and interventions to improve older drivers' self-awareness of driving ability. Early detection of older drivers with inaccurate self-awareness of driving ability is necessary to educate these clients about the impact of changes in functional abilities on driving ability and to promote appropriate self-regulatory behaviors using driver retraining or refresher programs (Friedland & Rudman, 2009; Owsley et al., 2003). It was found that for older adults without severe contraindications to driving or neurodegenerative diseases, their self-awareness of driving is associated with visuo-motor processing speed (cross-sectionally and longitudinally), executive function (longitudinally only), and number of comorbid medical conditions (cross-sectionally only). Clinicians could be more vigilant about these clinical features for identifying older drivers with declining driving ability, but who are unaware of these changes.

For older drivers who have declining driving ability, some jurisdictions have applied the policy of giving restricted licensing to allow them to continue to drive in limited and regulated situations. Some of the common restrictions given to older drivers include the prohibition of driving at night, restriction to areas under certain speed limits or restriction of driving within a limited radius from home (Marshall et al., 2002). Previous studies showed that these policies were under-applied (Langford & Koppel, 2011) but they were found to decrease the license holders' crash rates and traffic violations (Asbridge et al., 2017; Marshall et al., 2002; Langford & Koppel, 2011). The application of restricted licenses not only requires the authorities to enforce these restrictions, but most importantly, also entails self-awareness of driving ability to restrict their driving conditions voluntarily in their everyday life. The findings from this thesis could be applied to help identify the most appropriate older drivers who may be more fit to apply the restricted licencing by having good self-awareness to drive safely in their familiar driving environment examined using the NDO approach.

7.6 CONCLUSION

The research presented in this thesis contributed evidence towards our understanding of older drivers' self-awareness of driving ability in their naturalistic driving environment and the challenges involved in its measurement. These findings will help clinicians in the identification of older drivers with inaccurate self-awareness of their driving ability and in the development of tailored driving refresher and retraining programs for those who over- and under-estimate their driving ability. They could also assist licensing authorities in their implementation of restricted licensing for seniors.

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APPENDIX 1. The PDA questionnaire

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PERCEIVED DRIVING ABILITIES
(Appendix L)

SITE # [ ][ ] - PT ID [ ][ ][ ][ ]   Date: [ ][ ] dd / [ ][ ] mm / [2][0][ ][ ] yyyy

Candrive — Driving research for older adults. Au volant de la recherche sur les aînés.

Visit: ○ Year 1 (Baseline) ○ Year 2 ○ Year 3 ○ Year 4 ○ Year 5

How would you rate your current ability to …
Assume daytime driving unless specified otherwise (night)

Please fill in one of the circles that best describes your answer.

	Poor ▼	Fair ▼	Good ▼	Very Good ▼
1. See road signs at a distance?	○	○	○	○
2. See road signs at a distance at night? ○ **Do not drive at night**	○	○	○	○
3. See your speedometer and controls?	○	○	○	○
4. See pavement lines at night? ○ **Do not drive at night**	○	○	○	○
5. Avoid hitting curbs or medians?	○	○	○	○
6. See vehicles coming up beside you?	○	○	○	○
7. See objects on the road (at night) with glare from lights or wet roads? ○ **Do not drive at night**	○	○	○	○

PERCEIVED DRIVING ABILITIES
(Appendix L)

SITE #	PT ID	Date: dd / mm / 2 0 yyyy

Visit: ○ Year 1 (Baseline) ○ Year 2 ○ Year 3 ○ Year 4 ○ Year 5

How would you rate your current ability to ...

Assume daytime driving unless specified otherwise. (night)

	Poor ▼	Fair ▼	Good ▼	Very Good ▼
8. Quickly spot pedestrians stepping out from between parked cars?	○	○	○	○
9. Move your foot quickly from the gas to the brake pedal?	○	○	○	○
10. Make an over the shoulder check?	○	○	○	○
11. Quickly find a street or exit in an unfamiliar area and heavy traffic?	○	○	○	○
12. Get in and out of your car?	○	○	○	○
13. Reverse or back up?	○	○	○	○
14. Make quick driving decisions?	○	○	○	○
15. Drive safely? (avoid accidents)	○	○	○	○

PERCEIVED DRIVING ABILITIES
(Appendix L)

SITE # ☐☐ - PT ID ☐☐☐☐   Date: ☐☐ / ☐☐ / 2 0 ☐☐ (dd / mm / yyyy)

Visit: ○ Year 1 (Baseline) ○ Year 2 ○ Year 3 ○ Year 4 ○ Year 5

Candrive

Compared to 10 years ago, how would you rate your own ability to ...

Please fill in one of the circles that best describes your answer.

	Better	Same	A Little Worse	A Lot Worse
16. See road signs at a distance?	○	○	○	○
17. See road signs at a distance at night?	○	○	○	○
18. See your speedometer and controls?	○	○	○	○
19. See pavement lines at night?	○	○	○	○
20. Avoid hitting curbs or medians?	○	○	○	○
21. See vehicles coming up beside you?	○	○	○	○
22. See objects on the road at night with glare from lights or wet road?	○	○	○	○

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PERCEIVED DRIVING ABILITIES
(Appendix L)

SITE # - PT ID	Date: dd / mm / 2 0 yyyy	Candrive

Visit: ○ Year 1 (Baseline) ○ Year 2 ○ Year 3 ○ Year 4 ○ Year 5

Compared to 10 years ago, how would you rate your own ability to ...

	Better	Same	A Little Worse	A Lot Worse
23. Quickly spot pedestrians stepping out from between parked cars?	○	○	○	○
24. Move your foot quickly from the gas to the brake pedal?	○	○	○	○
25. Make an over the shoulder check?	○	○	○	○
26. Quickly find a street or exit in an unfamiliar area and heavy traffic?	○	○	○	○
27. Get in and out of your car?	○	○	○	○
28. Reverse or back up?	○	○	○	○
29. Make quick driving decisions?	○	○	○	○
30. Drive safely? (avoid accidents)	○	○	○	○

Date you completed this form: dd / mm / 2 0 yyyy

THANK YOU!

APPENDIX 2. Additional eDOS information

Appendix 2.1 Original eDOS administration procedure and formula of eDOS total score

Retrieved from Koppel et al. (2012). Ozcandrive/Candrive Driving Observation Schedule: Manual and Scoring Instructions for eDOS.

The electronic Driver Observation Schedule (eDOS) is an on-road driving task, designed initially for use in the Ozcandrive study to evaluate older drivers' everyday driving behavior in order to monitor changes in individual driving behaviors over time1. Key features of eDOS include observation of drivers in their own vehicle and on roads that are part of their familiar driving environment. The P-E Fit theory of driving competence and Michon's Model of Driver Behavior were used to guide the development of the eDOS item bank. Previous older driver research was reviewed, including: older driver crash epidemiology, older driver self-regulatory behaviour, and published driving measure to assist with item selection and operationalization. Based on these findings, categories of driving behaviors were identified for inclusion in the final observation schedule: a) observation of road environment, b) signaling, c) speed regulation, d) gap acceptance, e) lateral lane positioning, f) road-rule compliance, and g) vehicle positioning.

The eDOS was designed to commence from participants' homes and be conducted on roads familiar to and chosen by participants, travelling to up to four locations within their local area. Whilst the driving route itself is not standardized, the eDOS has standardized procedures for observation and documentation of driving behaviors (both inappropriate and appropriate) that occur during intersection negotiation, lane-changing, merging, maneuver-free driving and low speed maneuvering, characterized by different levels of complexity (traffic density, speed zone and number of road lanes).

The observer is also required to document the occurrence of 'critical errors', defined as errors which result in: 1) the observer terminating the DOS; 2) the vehicle being involved in a crash or near-crash, and/or 3) the observer using verbal prompts either to prevent an error escalating in severity or to correct the error.

Scoring:

The total DOS score (maximum 100 points) is a function of three components:

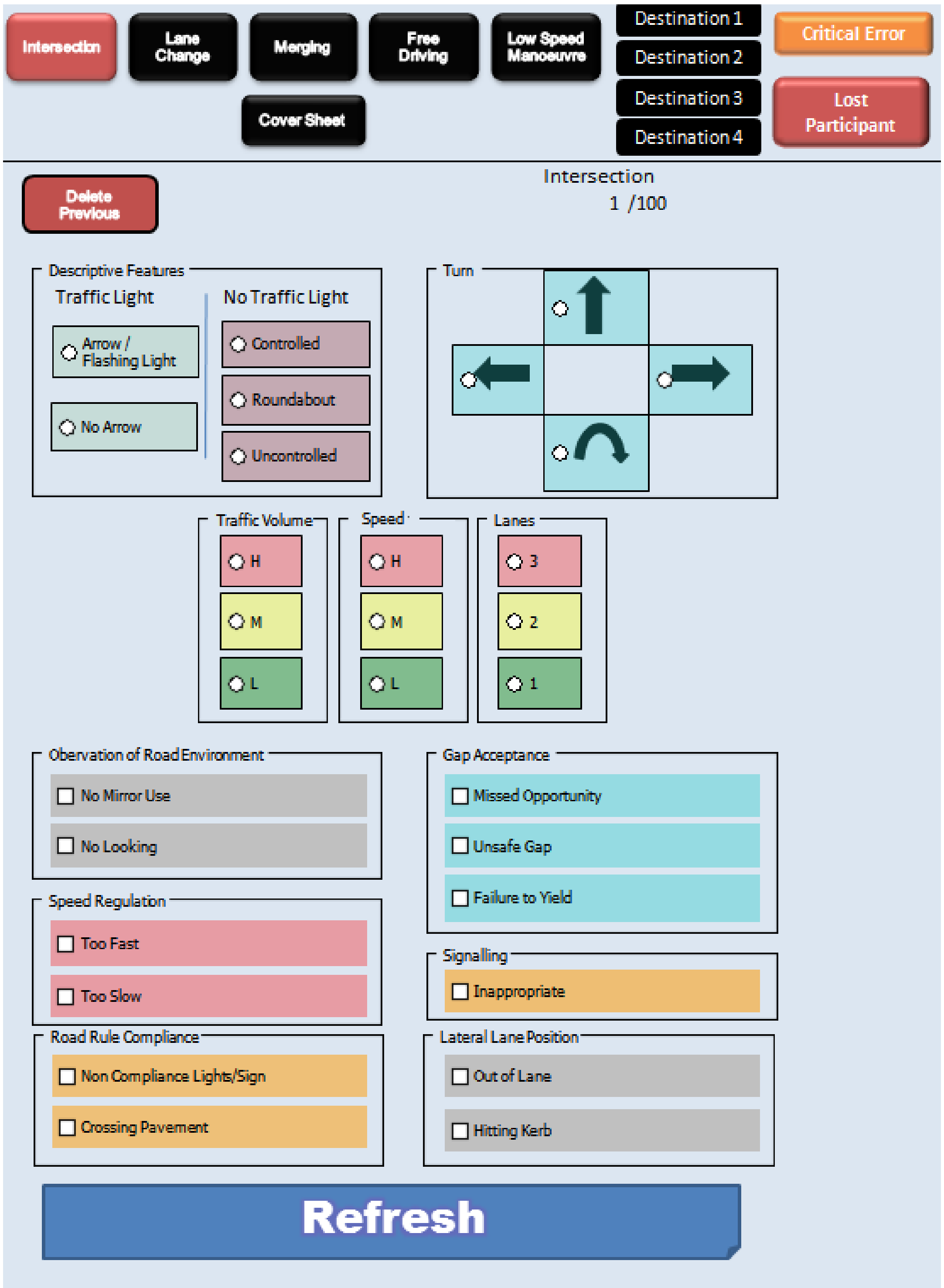
The total number of driving behaviors completed appropriately, divided by the total number observed, less one point for each error performed during maneuver-free driving and less two points for each critical error, multiplied by 100.

$$\frac{Total\ number\ of\ observation\ -\ (1\ \times number\ of\ inappropriate\ behaviors\ +2\ \times\ critial\ error)}{Total\ number\ of\ observation} \times 100$$

Observer Seating

The observer should sit in the rear passenger side seat of the participant's car (in the left rear passenger side seat for right hand drive vehicles). Observers may also choose to sit in the front passenger seat, however they should ensure that they have a good view of the driver, the speedometer and the vehicle controls.

Appendix 2.2 The eDOS scoring sheet



Appendix 2.3 Definition of driving errors on the eDOS

Type of Error	Specific Error	Explanation
Observation of Road Environment: maintaining awareness of surroundings and road environment	**No Mirror Use**	If Participant does not use rear-view and side-view mirrors
	No looking	If Participant fails to look ahead, or does not look left or right before proceeding through an intersection.
Speed Regulation: adhering to posted speed limits, and further regulating speed in consistence with road/traffic conditions and driving intentions	**Too Fast**	If Participant drives over the speed limit or at dangerous speeds for manoeuvre
	Too Slow	If Participant drives too slowly; (consistently; a sign of overcautiousness)
Road-Rules Compliance: ability to follow and appropriately respond to road signs (eg. stop signs, traffic lights) and not cross pavement markings	**Non Compliance Light/Sign**	If Participant fails to comply with either a road sign or traffic light.
	Crossing Pavement	If Participant crosses a pavement marking to the extent of disturbing other road users
Gap acceptance: making safe judgments about the presence of other vehicles and consequently selecting a suitably risk-free point to pull into a line of traffic, or cross one or more lanes of traffic	**Missed Opportunity**	Being overcautious and missing opportunities when participant estimates gap acceptance
	Unsafe Gap	Participant selects an unsafe gap
	Failure to Yield	If Participant fails to yield (give right of way)
Signalling: ability to signal his/her intention to negotiate an intersection.	**Inappropriate**	If Participant leaves the signals on after negotiating an intersection, or puts on the incorrect signal and/or if the Participant does not use signals
Lateral Lane Position/Vehicle Positioning: position of the vehicle (lateral) whilst moving or stopped, in accordance to the side lane markings on a motorway	**Out of Lane**	If Participant drifts out of lane (with or without marked lanes)
	Hitting Kerb/Curb	Participant hits a side kerb/curb
	Inappropriate Following Distance	Driving too close to the vehicle in-front
Low Speed Manoeuvre: when the participant is parking, reversing or pulling into the kerb/curb	**No Observation**	Not looking behind when reversing
	Signaling Misuse	Not signaling appropriately
	Inappropriate Positioning Attempts	Excessive attempts at parking/positioning the vehicle appropriately

Appendix 2.4 Definition and categorization of driving maneuver/environment complexity

- Directional intersection -- Intersections with a flashing green light or a directional arrow to give the priority of road use.
- Nondirectional intersection -- -- Intersections where drivers need to follow the traffic rules and judge the best timing to execute their action. Examples of nondirectional intersections are intersections with a stop sign, a solid green light, or no road sign or signal.
- Residential street -- Streets with one or two lanes that usually have low speed limit (< 50 km/hr) and low traffic volume.
- Major road -- Arterial road with more than two lanes, speed limits between 50 km/hr and 70 km/hr, and moderate to high traffic between 7 am and 11 pm. Examples of major road include boulevard and service road.
- Highway driving -- Highway or road with speed limit higher than 70 km/hr.

Speed limit	Number of lanes	Driving environment complexity
1	1	Residential street
1	2	Residential street
1	3 or more	Major road
2	1	Major road
2	2	Major road
2	3 or more	Major road
3	1, 2, 3 or more	Highway or driving at higher speed zone

Note: Speed limit 1= low speed limit, 2=moderate speed limit, 3= high speed limit

APPENDIX 3. Consent form for the survey study

Consent Form for Participation

Title of project: **Weighting road complexity and error severity for scoring the electronic Driving Observation Schedule (eDOS)**

Researchers: Yu-Ting Chen, PhD Candidate, Barbara Mazer, Ph.D, & Isabelle Gélinas, Ph.D, McGill University

INTRODUCTION

You have been invited to participate in a research project that involves completing two surveys to develop a weighted scoring procedure for the eDOS (electronic Driving Observation Schedule) total score. Before accepting to participate in this project, please take the time to carefully review and understand the following information. This consent form explains the purpose of the study, the procedures, the benefits, the risks and inconveniences as well as the individuals you can contact if necessary.

DESCRIPTION OF THE STUDY AND ITS PURPOSE

The study researchers would like to develop a weighted scoring procedure for the eDOS (electronic Driving Observation Schedule) total score. The electronic Driving Observation Schedule (eDOS) provides an unobtrusive evaluation of ecological driving using the driver's own vehicle in his or her familiar environment. There is currently a standard approach to recording the driving environment and the errors that clients make while driving, however the eDOS global score currently gives the same weight to all types of errors. This means that failing to signal in a quiet residential area is weighted equally to failing to stop completely at a stop sign or not observing the environment when merging into traffic. We are in the process of developing a weighted scoring system and in order to do so, we are consulting experts in the field of driving rehabilitation to help determine the appropriate weight associated with each type of driving error.

NATURE AND DURATION OF PARTICIPATION

Your participation in this study will involve completing two separate surveys. For the first survey, you will be asked to rate the difficulty of maneuvering in different driving environments and rank these environments in terms of difficulty. It will take approximately 10 minutes to complete. A second survey will be sent to you approximately one month later asking you to rate the level of risk associated with different driving errors in specific driving environments. This will take about 20 minutes to complete.

PERSONAL BENEFITS FROM PARTICIPATING

You will not personally benefit from taking part in this study. However, the results of this study should help improve the scoring of a new ecological evaluation of driving performance.

INCONVENIENCES ASSOCIATED WITH PARTICIPATING
The only inconvenience associated with participating in this study is the time that you will devote to completing the two surveys.

CONFIDENTIALITY
All personal information gathered about you during the study will be coded in order to ensure its confidentiality. This data will be kept under lock and key at the Jewish Rehabilitation Hospital by the person in charge of this study for a period of five years following the end of the study, after which it will be destroyed. The members of the research team will be the only ones to have access to the information. However, should the research project be subject to a control by the CÉR of the CRIR or by the department of Ethics of the Ministry of Health and Social Services of Quebec, your file could be consulted by an individual who will be required to follow strict confidentiality guidelines. In the event that the results of this study are presented or published, no information identifying the participants will be included.

AUTORISATION FOR USING THE RESULTS

You accept that the obtained information will be used for scientific and educational purposes in a complete confidential manner.

VOLUNTARY PARTICIPATION AND WITHDRAWAL OF PARTICIPANTS
Your participation in the research study described above is completely voluntary. It is understood that you can, at any time, end your participation without any consequences by informing the researcher. In the case of a withdrawal, only the information provided prior to the withdrawal will be used with your consent. However, if you chose to withdraw your consent, the information you provided will not be used.

RESPONSABILITY CLAUSE
While agreeing to participate in this study, you do not give up any of your legal rights nor release the researchers, sponsors or institutions involved of their legal and professional obligations.

COMPENSATOIRY INDEMNITY
You will not receive a compensatory indemnity for your participation in this project.

CONTACT PERSONS
Should you have any questions regarding this study, please feel free to contact Isabelle Gélinas at (514) 398-4514 or by e-mail isabelle.gelinas@mcgill.ca.

If you have any questions about your rights and recourse or your participation in this research study, you can contact Me Anik Nolet, Research Ethics Co-coordinator for the CRIR'S Institutions at (514) 527-4527 extension 2649 or by e-mail anolet.crir@ssss.gouv.qc.ca.

CONSENT

I state that I have read this consent form. I understand this study, the nature and extent of my participation, as well as the benefits and risks/inconveniences to which I will be exposed as presented in this form.

I voluntary agree to take part in this study. I understand I can withdraw from the study at any time without prejudice. I certify that I have had sufficient time to consider my decision to participate in this study.

If you agree to participate, please click here ____

APPENDIX 4. Consent form for the eDOS study

<u>Consent Form</u>
<u>for my participation in a research project</u>

Name of Participant: ____

Title of Project: **The CanDRIVE Common Cohort Study: On-Road Driving Observation**

Principal Investigators:
Isabelle Gélinas (McGill University)
Barbara Mazer (McGill University)
Brenda Vrkljan (McMaster University)

Sponsor: Auto21 Network Centres of Excellence, awarded a two-year, $200,000 grant

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You are being invited to participate in a research study conducted by CanDRIVE researchers. Only participants in the CanDRIVE project are being invited to participate.

SOME GENERAL THINGS YOU SHOULD KNOW ABOUT RESEARCH STUDIES

To decide whether or not you want to be a part of this research study, you should understand what is involved and the potential risks and benefits. This consent form explains the purpose of this study, the procedures, advantages, risks and inconvenience as well as the persons to contact if you have concerns or questions. Please feel free to ask the research personnel or researchers on this project to explain anything that is not clear. Also, we invite you to ask the research team any questions that you may have. Once you understand the study, you will be asked to sign this form if you wish to participate. Please take your time when making your decision. Feel free to discuss it with your friends and family.

WHY IS THIS RESEARCH BEING DONE?

The five-year CanDRIVE study is following older drivers to examine the medical and functional conditions that occur with age that can affect driving ability. While the CanDRIVE cohort study will provide information on the effect that these conditions have on the risk of having an automobile crash, the current study will look more closely how these conditions affect actual natural driving performance.

WHAT IS THE PURPOSE OF THIS STUDY?

The health care professionals conducting this research study are attempting to better understand the on-road driving behaviours of seniors that occur during everyday driving and to track these across time. This is being done to provide a more in-depth understanding of actual performance behind-the –wheel. If specific on-road difficulties are found to occur in older drivers, this information can be used to target future training programs as well as innovations in vehicle design and roadway engineering.

HOW MANY PEOPLE WILL BE IN THIS STUDY?

A total of 50 CanDRIVE participants will be enrolled from three sites (Montreal, Ottawa and Hamilton). Fifty will be participating in the Montreal area.

WHAT WILL MY RESPONSIBILITIES BE IF I TAKE PART IN THIS STUDY?

If you volunteer to participate, we will ask you to do the following things over the next two years:

The research assistant will explain the purpose and procedures of this additional study to you. If you agree to participate, you will receive a call from a graduate student and s/he will arrange to meet with you in your home at a time that is convenient to you. When the student comes to your home to review the details of the study, you will be asked to identify places that you commonly drive (e.g. the local service station, grocery store, doctor's office, recreation centre, friends' home, etc.). Once you have selected 2 places that you would like to drive for this study, you will be asked to think about a possible route to get to these places and the student will mark out this route on a map. Together you will arrange a time for the driving observation. Two graduate students will then return to your home and will review the driving destinations that you selected as well as the driving route. Video recording cameras will then be installed in your own car to record the driving environment in front of you as well as what you do when driving. You will drive as you normally do to the places that you selected. The two students will meet you at the final destination. The intention is to do this observation this year as well as 9 months from now.

This is not an evaluation of your driving skills; it is simply an observation of the driving that you do in your natural driving environment. It will be conducted on routes familiar to and chosen by you, in your own vehicle, and will take only 20-25 minutes to complete.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?

As this is an observation of the driving that you usually do, there is no additional risk over and above that associated with your normal driving. You may find that having the small video cameras in your car can make you nervous. If this happens, we will try to answer your concerns and help you become relaxed in the vehicle. If you should feel too uncomfortable or fatigued, you can decide whether to continue or postpone the assessment.

It is possible that the driving observation may detect driving behavior that is unsafe. In this case, your family physician will be notified and will then evaluate whether further steps are necessary to ensure your driving safety. You will be notified should this be necessary.

This may involve in-depth assessment or management of medical problems and on occasion may require that your family physician notify the licensing bureau, the Société de l'assurance automobile du Québec (SAAQ). The SAAQ may, if your health condition seriously affects your driving safety, require that you stop driving.

WHAT ARE THE POSSIBLE BENEFITS FOR ME AND/OR FOR SOCIETY?

While there may be no direct benefits to you from participating in this study, the results of this study may contribute to improving the safety of older drivers as a group.

CONFIDENTIALITY - INFORMATION WILL BE KEPT PRIVATE

If you choose to participate, all information gathered about you will be kept confidential and will be securely stored. No one except the researchers and individuals involved directly in this study will have access to information. However, in the event that the project is audited, it is possible that the data may be reviewed by someone with a mandate from the Ethics Committee or a representative from the Canadian Institutes for Health Research (CIHR), which adheres to strict confidentiality policies. Your data, with all identifying information removed, and replaced with a study number, will be securely stored in a locked research office or on a secure computer server. A list linking the number with your name will be kept in a secure place in Montreal, separate from your file, so that no one except the study coordinators and researchers in Montreal can link your name with your data. Also, your data will not be shared with anyone outside of the study except with your consent or, as required by law. All of the data for this research study will be retained for 15 years after the end of the study. Following this 15 year period, the data will be destroyed beyond recovery.

If the results of the study are published, your name will not be used and no information that discloses your identity will be released or published without your specific consent. However, it is important to note that this original signed consent form and the data about your assessments may be included in your health record.

WHAT IF I DO NOT WANT TO PARTICIPATE OR WANT TO WITHDRAW?

You are under no obligation to participate, and you may withdraw from this study any time and for any reason by notifying the researchers at the numbers indicated below. If you decide not to participate, or to withdraw, your decision will in no way affect current or future care you receive. Your study information will be retained for study purposes for 15 years.

RESPONSIBILITY CLAUSE

While agreeing to participate in this study, you do not give up any of your legal rights nor release the researchers, sponsors, or institutions involved of their legal and professional obligations.

WILL I BE INFORMED ABOUT NEW INFORMATION

If any new information about the study becomes available that might affect your willingness to participate, the study team will inform you.

COMPENSATORY INDEMNITY

You will not be paid to participate. There is no cost associated with participating.

WHO DO I CONTACT IF I HAVE QUESTIONS OR CONCERNS?

If you have any questions or concerns about this study please feel free to contact the Montreal study investigators, Isabelle Gélinas at (514) 398-4514 or Barbara Mazer at (450) 688-9550.

If you have any questions about your rights or concerns about your participation in this research study, and want to speak to someone other than the researchers and the research personnel, you may contact Me Anik Nolet, Research Ethics Co-ordinator for the CRIR'S Institutions at (514) 527-4527 extension 2649 or by e-mail: anolet.crir@ssss.gouv.qc.ca.

CONSENT

I state that I have read this consent form. I understand this study, the nature and extent of my participation, as well as the benefits and risks/inconveniences as presented in this consent form. I have been given the opportunity to ask questions concerning the study and have received answers to my satisfaction.

I voluntary agree to take part in this study. I can withdraw from the study at any time without it affecting any care I receive. I have had sufficient time to consider my decision to participate. I will receive a signed copy of this consent form and another will be placed into my file.

NAME OF PARTICIPANT (print)	**SIGNATURE OF PARTICIPANT**
______________________________	______________________________

Signed at ____________________________ , the ___________, 20 _____.

<u>Responsibility of the principal investigator</u>

I, the undersigned, __________________________________, certify
(print name)

(a) having explained to the research participant the terms of this form
(b) having answered all the questions he/she as asked in this regard

(c) having clearly indicated that he/she remains free, at any time, to end his/her participation in the
above described research study
(d) that I will give him/her a signed and dated copy of this form.

____

Signature of the Principal Investigator
or representative

Signed at ___________________________, the _______________ 20 __.