

Original Research Report

Toward the Multilevel Older Person's Transportation and Road Safety Model: A New Perspective on the Role of Demographic, Functional, and Psychosocial Factors

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Abstract

Objectives. Self-regulation refers to the practice of using self-imposed restrictions to protect oneself from situations that are, or are perceived to be, unsafe. Within the driving context, self-regulation refers the compensatory practices that some older adults adopt to restrict their driving to situations in which they feel safe. However, the way in which demographic, functional, and psychosocial factors, and the interactions between these factors, influence older adults' driving self-regulation is not well understood. Improving this understanding could lead to new ways of considering the mobility concerns faced by older drivers.

Method. A systematic review of the current literature was conducted to explore this issue. Twenty-nine empirical studies investigating the factors associated with older adults' self-regulatory driving behaviors were examined.

Results. The review findings were used to construct the Multilevel Older Persons Transportation and Road Safety (MOTRS) model. The MOTRS model proposes that individual and environmental factors such as age, gender, and the availability of alternative transportation predict older adults' practice of driving-related self-regulation. However, these variables influence self-regulation through psychosocial variables such as driving confidence, affective attitude, and instrumental attitude toward driving.

Discussions. The MOTRS model extends previous attempts to model older adults' driving by focusing on a novel target, driving self-regulation, and by including a wider range of predictors identified on the basis of the systematic literature review. This focus enables consideration of broader mobility issues and may inform new strategies to support the mobility of older adults.

Key Words: Driving—Driving self-regulation—Mobility—Older adults—Safety.

The older adult population (adults aged 55 or older) is projected to rapidly increase over coming decades (e.g., [Organisation for Economic Co-operation and](#)

[Development, 2009](#)). This demographic change has important implications for many communities, one of which is how to sustain the mobility and activity of older persons.

There is an extensive body of literature related to older adult drivers, but relatively few attempts to integrate findings across studies or to develop models of driver behavior. This has resulted in a body of literature that is somewhat disjointed. A model of older adult driving behavior is important to advance our understanding of the issues that affect older adult drivers and their mobility needs. It can help to identify underlying mechanisms and establish priorities for the change that can be addressed through planning or interventions.

There are two previous models that seek to account for the behavior of older adult drivers: the 2005 Multifactorial Model of Older Driver Safety that identifies cognitive, sensory, and physical factors as relevant to safety (Anstey, Wood, Lord, & Walker, 2005) and the 2010 Driving as Everyday Competence Model proposed by Lindstrom-Forneri, Tuokko, Garrett, and Molnar (2010), which added to these factors and many others, including social and environmental factors. An important contribution of the widely cited Anstey and colleagues' model was that it identified self-monitoring as a mediating factor in the relationship between functional decline from aging and driving. The inclusion of additional contextual factors by Lindstrom-Forneri and coworkers (2010) reflects a growing recognition of a need to consider a wider range of factors as relevant to driving and transport needs of older adults than previously occurred. A limitation of the Lindstrom-Forneri and coworkers (2010) model is that it was not constructed following a systematic literature review. This raises questions about the selection of, and evidence for, its components. A limitation of both models is that they do not explain the processes that link the identified components or explain their relative importance, with the effect that they provided a most static description of relations.

The purpose of this article was to conduct a systematic literature review that was focused on self-regulation (SR) and to propose a new theoretical model of driving in older adults based on that review. SR of driving by older adults is suggested as a means of ensuring safety and maintaining mobility. Although SR of driving is a concept that has been described for over a decade, publications addressing older adult driving SR have recently increased. The question for communities, policy makers, and clinicians is whether SR is an effective strategy, whether it can be improved, and for whom it might be a safe recommendation. Having a model of SR for older adult drivers is important to address these questions.

SR: Definition and Rationale for Becoming the Focus of a New Model

SR refers to the practice of adjusting or reducing driving in response to changes in health and functional abilities (Donorfio, D'Ambrosio, Coughlin, & Mohyde, 2009). Specifically, as driving in certain conditions become more

difficult because of increasing resource limitations (e.g., reduced visual acuity or reduced cognitive ability), older drivers may restrict their driving to those times and conditions in which they feel safe (Ball et al., 1998; Hakamies-Blomqvist & Wahlstrom, 1998; Stalvey & Owsley, 2000). Examples of SR reported by older drivers include avoiding driving at night, in the rain, or when "complex" maneuvers are required, such as turning across oncoming traffic (e.g., Baldock, Mathias, McLean, & Berndt, 2006; Charlton et al., 2006; Sullivan, Smith, Horswill, & Lurie-Beck, 2011). The primary difference between SR and mandatory restriction of driving to specific situations is that the practice (both frequency and type) of SR is voluntary and is based on the assessment of individual older drivers themselves.

Some studies report that the majority of older adults self-regulate their driving (e.g., 60%, Ruechel & Mann, 2005; 80%, Ball et al., 1998), whereas others demonstrate low rates of SR (8%, Baldock et al., 2006; 25%, Charlton et al., 2006; 17.5%, Horswill, Anstey, Hatherly, Wood, & Pachana, 2011; 35%–45%, Hakamies-Blomqvist & Wahlstrom, 1998; 25%, Molnar & Eby, 2008). This variation is probably due to the use of different research definitions. Studies that measured SR as a reduction of mileage generally report a higher proportion of self-regulating older drivers than do studies that define SR *situationally*; that is, as a reduction in driving in specific situations. When defined as restricting driving to specific situations *for safety reasons*, an even lower rate of SR is reported. A complication with mileage definitions is that they measure exposure independent of context; so low mileage cannot be interpreted as evidence of SR. A complication with situational measures is that changed driving patterns (such as minimal night-time driving) could be due to broader social and environmental factors (such as decreased social engagement and increased financial restrictions) and not directly related to safety (e.g., Ball et al., 1998; Blanchard, Myers, & Porter, 2010; Myers, Paradis, & Blanchard, 2008). Charlton and coworkers (2006) reported that more frequent reasons for reducing driving were change in employment status (34%) or changes in lifestyle (38%), whereas relatively few drivers identified health (17%) and driving-related factors (6%) as relevant. The difficulties in developing a shared understanding of this behavior may be addressed by making explicit the contributing factors, through the development and articulation of a model.

Systematic Review of the Literature on Factors Associated With Driving-Related SR in Older Adults

Selection of Literature

Relevant data were gathered by performing systematic literature searches of the MEDLINE, PsychInfo, Ejournal, ScienceDirect, EMBASE, and PUBMED databases. Peer-reviewed articles on factors associated with driving-related SR were identified using

the following search terms (English language, peer reviewed only, published within the year 1998–2013): self-regulat* (i.e., included search terms such as self-regulate, self-regulating, self-regulatory, and self-regulation), self-restrict*, self-limit*, compensat*, avoidance, older, senior, elderly, and driv*. Inclusion criteria were reporting of associations (odds ratios, correlations) or *p* values for associations between predictors and SR (self-report or objective measures), in adults aged 55 or older. Reference lists of relevant articles were also used to identify potential studies for inclusion. After the initial perusal of the titles and abstracts, 58 articles were selected for further review. These 58 articles were reviewed in full using the method described by Wright, Brand, Dunn, and Spindler (2007). Studies were excluded if they did not provide enough information for a systematic review (e.g., poster presentations), adopted qualitative methods, or used the same group of participants as previously included studies. The selection process is described in a flow diagram adapted from the PRISMA Flow Diagram (Figure 1; Moher, Liberati, Tetzlaff, Altman, & The PRISMA Group, 2009). This process resulted in 29 included studies.

and coworkers (2005). The quality rating was derived by summing a component for sample size ($N > 1,000 = 3$, $N = 200-1,000 = 2$, $N < 200 = 1$), outcome measure (objective driving = 2, self-report = 1), and design (prospective = 2, retrospective or concurrent = 1). Higher ratings suggest a better quality study. Two independent raters applied the quality rating to all studies. A two-way mixed, absolute average-measures intraclass correlation was used to measure interrater reliability of overall study quality ratings ($ICC = 0.96$), with a high degree of agreement between raters (Hallgren, 2012). The discrepancies between ratings were then discussed and resolved until perfect agreement was reached.

Method

Quality Ratings

Eligible studies were assigned a quality rating. Quality ratings were determined using the process described by Anstey

Results

Table 1 summarizes the findings of each of the 29 studies that were included in the review. This table has a description of the sample and study design, and it shows the quality rating for each study. This table shows that most (27/29; 93.10%) of the studies used *self-report* methods to assess SR (e.g., questionnaires; Table 1), especially the Driver Habits Questionnaire (DHQ), but not necessarily all or the same DHQ items (e.g., Vance et al., 2006 used 10 DHQ items, whereas Ackerman et al., 2011 used 6 DHQ items). For the purpose of this article, unless otherwise

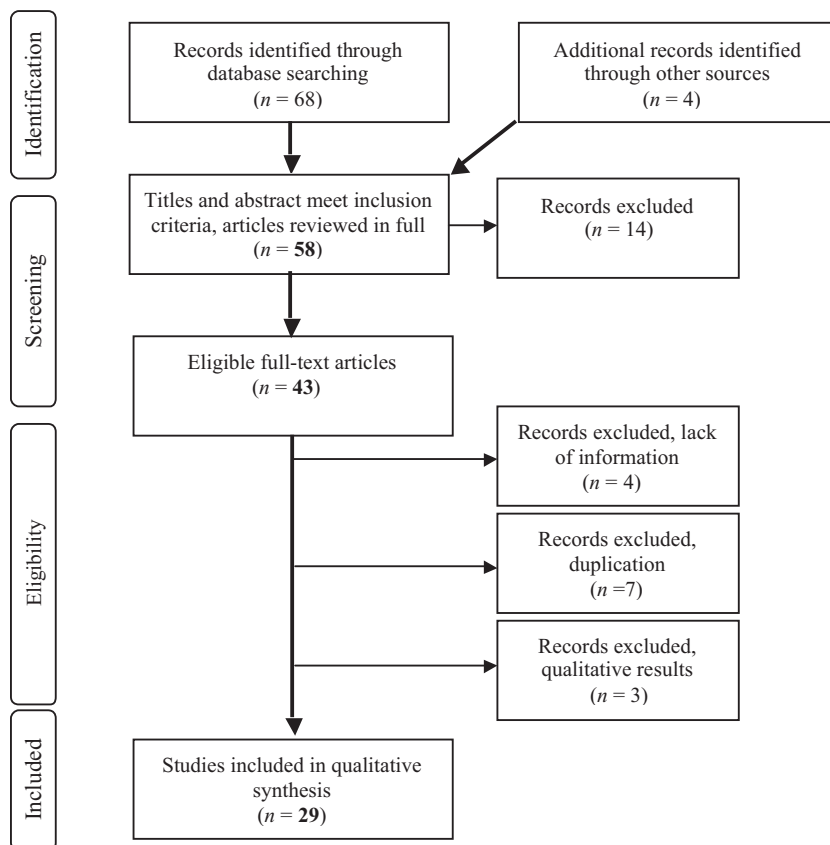


Figure 1. Flow diagram of the article identification and selection process.

Table 1. Methodological Details of Reviewed Studies, Presented in Chronological Order

Study	Design	Sample (age) ^a	Predictors	Outcome measures	Outcomes	Final rating
Ball et al. (1998)	Correlational (interview)	257 drivers (M = 70, 56–90)	Ophthalmologist assessment; UFOV; MOMSSE	Self-report: DHQ (5 item; 1 “never” to 5 “always”)	Signification associations between visual and attentional impairment and SR	2 + 1 + 1 = 4
Rimmó & Hakamies-Blomqvist (2002)	Correlational (self-report questionnaire)	939 drivers (55–75+)	Age, gender, self-report health, and driving behavior	Self-report: 5 item (yes/no)	Older drivers, and female drivers, are more likely to report SR Impaired health, inattention and inexperience related driving errors related to SR (after controlling for age and gender)	2 + 1 + 1 = 4
West et al. (2003)	Correlational (interview)	629 drivers (65+)	Lighting and contrast vision tests, and self-report questionnaire	Self-report: (yes/no)	Self-regulators more likely to be older, female, with lower memory scores, failed walking and hearing test, reported arthritis and stroke, and performed worse on vision tests	2 + 1 + 1 = 4
Ragland et al. (2004)	Correlational	2,046 drivers (55–75+)	Self-report health conditions; MMSE; SKILL card	Self-report: 14 medical and 7 medical reason to SR (yes/no)	Older women more likely to report SR Vision is most cited medical reason to regulate Safety and crime are most cited non-medical reasons to regulate	3 + 1 + 1 = 5
Baldock et al. (2006)	Correlational	104 drivers (M = 74.2, 60–92)	Self-report questionnaire; of driving confidence, driving and mobility related information, and driving assessment	Self-report: DHQ (1 “never” to 5 “always”)	On-road diving ability was not significantly correlated with overall SR, but only in specific situations Lower levels of SR was found among those with higher levels of driving confidence, perceived barriers in maintaining lifestyle, unavailability of family and friends to provide assistance	1 + 1 + 1 = 3

Table 1. *Continued*

Study	Design	Sample (age) ^a	Predictors	Outcome measures	Outcomes	Final rating
Charlton et al. (2006)	Correlational (telephone interviews)	656 drivers (55–75+)	Self-report questionnaire of sociodemographic information, health, and driving history	7 items (yes/no)	Self-regulators are more likely to be female, older, not the principal driver in the household, had been involved in a crash in the last 2 years, reported vision problems and had lower driving confidence ratings	2 + 1 + 1 = 4
Vance et al. (2006)	Cross-sectional (interview +self-report questionnaire)	815 drivers (M = 71.61, 55–92)	Gross Impairment Screening Battery; Rapid Walk subtest; MVPT; Trail Making test; UFOV; Self-report health conditions	DHQ 10 items	Health, physical functioning, and cognitive functioning partially mediated the effects of age and gender on SR	2 + 1 + 1 = 4
Okonkwo et al. (2008)	Cross-sectional (interview + self-report questionnaire)	1,543 drivers years (M = 79.73, 75–100)	UFOV; demographics questionnaire; self-report health condition	DHQ (8 items (1 “never” to 5 “always”))	Self-regulators across driving situations are more likely to be older, female, lowered self-report health status, reported vision related problems, less driving exposure and prior crash involvement, performed worse on UFOV	3 + 1 + 1 = 5
D’Ambrosio et al. (2008)	Correlational (self-report questionnaire)	3,824 drivers (50+)	Self-report gender, age, health conditions, living arrangement	7 items (1 “absolutely never” to 4 “usually not affect willingness to drive”)	Self-regulators more likely to be women, older, reported poorer health, living with someone Effects of gender on SR mediated by age and health status	3 + 1 + 1 = 5
Kostyniuk & Molnar (2008)	Correlational telephone survey	961 drivers (65–85+)	Self-report overall health, vision, and physical functioning	3 items (1 “drive yourself” to 6 “Cancel or change the appointment”)	Self-regulators more likely to report mobility issues and vision-related problems, more likely to be female and older	2 + 1 + 1 = 4
Molnar & Eby (2008)	Correlational (clinical assessment)	68 drivers (65+) medical patients referred by physicians for driver assessment program	On-road driving course	6 items (yes/no)	Driving confidence only statistically significant for night driving and expressway driving only	1 + 1 + 1 = 3

Table 1. Continued

Study	Design	Sample (age) ^a	Predictors	Outcome measures	Outcomes	Final rating
			Clinical assessment of medical and driving history, vision, perception, physical abilities, cognitive skills and driving knowledge (UFOV, MFPT, Optic 2000 vision screen), clinical observation and physical examination		Poorer performance on-road driving significantly related to regulation of night driving Only visual impairment (not other impairments measured) related to SR	
Windsor et al. (2008)	Correlational (self-report questionnaire)	304 drivers (M = 77.13, 65+)	Self-report questionnaire of physical health, psychological well-being, potential barriers to self-regulate, perceived driving control and ability	4 items (1 "none of the time" to 5 "all of the time")	Self-report health, perceived driving control and driving ability relate to SR	2 + 1 + 1 = 4
Braitman & McCartt (2008)	Cross-sectional	N = 2,650 (Kentucky, Connecticut, and Rhode Island; age = 65+)	Self-rated memory impairment, vision impairment, physical functioning impairment, and medical conditions	Self-report self-limited driving practices (open-ended question)	Self-limit driving increased with driver age Those with impairments in memory, vision, and physical functioning, and with medical conditions were more likely to report self-limited driving	3 + 1 + 1 = 5
Ross et al. (2009)	Prospective cohort (5 years)	645 drivers (55–92)	Psychomotor (Rapid Walk and Foot Tap test); MVPT, UFOV	DHQ (1 "never" to 5 "always"; prospective 5 years)	High-risk group drivers increased driving avoidance over 5 years more than low-risk drivers	2 + 1 + 2 = 5
Sargent-Cox et al. (2011)	Correlational	322 drivers (M = 77.35, 65+)	Self-report health, health literacy, medical knowledge, and health experience	6 items (varied response format)	Health knowledge less predictive of SR than health experience. 85.7% participants reported poor knowledge regarding medication and driving	2 + 1 + 1 = 4

Table 1. *Continued*

Study	Design	Sample (age) ^a	Predictors	Outcome measures	Outcomes	Final rating
Blanchard et al. (2010)	Cross-sectional	61 drivers (<i>M</i> = 80.4, 65+)	SDF; DCS; PDA	SDA (20 item; 1 “not at all” to 4 “very much so”) GPS objective driving behaviors	Lowered comfort and perceived abilities significantly associated with SR, and overall driving exposure Neither sex nor age were predictive of any driving indicators	1 + 2 + 1 = 4
Lotfpour et al. (2010)	Correlational (interview + self-report questionnaire)	134 drivers 65+ from a senior center	mVF-14 questionnaire (self-report); Snellen Visual Acuity Test	DHQ 8 items (0 “never” to 4 “always”)	Significant negative correlation of the mVF-14 and Snellen with self-regulation	1 + 1 + 1 = 3
Ackerman et al. (2011)	Prospective cohort 3-month follow-up (clinical assessment + self-report questionnaire)	129 drivers (<i>M</i> = 78.73, 75–93)	UFOV; TICS-M; self-report health, mobility, driving ability and crash history	DHQ 6 items (1 “never” to 5 “always”)	Age, gender, TICS-M, self-report health, and medical conditions, UFOV performance and driving exposure significantly associated with SR Feedback regarding UFOV performance associated with increased driving avoidance at 3-month follow-up	1 + 1 + 2 = 4
Braitman & Williams (2011)	Prospective cohort (4 years); telephone interview	1,437 drivers (<i>M</i> = 74.3, 65+)	Self-report memory, vision and physical mobility impairment, medical conditions	10 items (0 “never avoid” to 3 “always avoid”)	Small increases in the number of driving situations avoided were associated with increased memory and mobility impairments	3 + 1 + 2 = 6
Horswill et al. (2011)	Correlational (self-report questionnaire and hazard perception test)	307 drivers (<i>M</i> = 74.76, 65–96)	HPT	18 item (yes/no)	Age-related declines in HPT not present in self-ratings Self-rated HPT performance and driving ability related to SR, but not objective test performance	2 + 1 + 1 = 4
Naumann et al. (2011)	Correlational (telephone questionnaire)	8,129 (18–75+) ^b	Self-report	4 item (yes/no)	Sex, income, and driving exposure associated with SR Vision impairment most commonly cited physical reason to reduce driving	3 + 1 + 1 = 5

Table 1. Continued

Study	Design	Sample (age) ^a	Predictors	Outcome measures	Outcomes	Final rating
Gwyther & Holland (2012) ^c	Correlational (self-report questionnaire)	395 drivers (M = 32.9, 18–78; n = 17 aged over 65 years)	Instrumental and affective attitudes related to driving (Lindstrom-Forneri et al., 2007); 18 items (1–5); MDSI 44 items (1–6)	DHQ 5 item (1 “never” to 5 “always”)	Although more commonly practiced among older drivers, SR was also evident in younger cohorts Women more likely to self-regulate Quadratic effect of age on SR was found (younger and older drivers more likely to SR than middle-year’s drivers) Linear relationship between age and SR once driving experience is controlled for Anxious driving style and affective attitude predictive of SR	2 + 1 + 1 = 4
O’Connor et al. (2010)	Retrospective cohort	597 drivers 65+	Balance (Turn 360) Depressive symptoms (CESD); Everyday functioning (EPT OTDL; TIADL) Visual acuity (Snellen) Memory (HVL; RBMT; AVLT) Reasoning (Letter Series test, Word Series, and Letter Sets) Self-rated health (1–5) Processing speed (WAIS-R; DSS; UFOV)	DHQ 8 item (1 “no difficulty” to 4 “extreme difficulty”)	Participants who were older showed more depressive symptoms, poorer self-rated health, vision and speed of processing were more likely to self-regulate	2 + 1 + 1 = 4
Wong et al. (2012)	Correlational	70 drivers (M = 71.47, 65+)	CDT Self-report health and driving ability	Modified DMQ-A (based on DHQ) 13 items (1 “never” to 5 “always”)	All reported high driving confidence and ability, included the proportion of drivers that failed the CDT test Those failed CDT significantly less likely to report SR	1 + 1 + 1 = 3

Table 1. *Continued*

Study	Design	Sample (age) ^a	Predictors	Outcome measures	Outcomes	Final rating
Meng et al. (2013)	Case-control (interview)	25 drivers (M = 74.4, 60+) Convenience sample of cognitive skills impaired drivers	Self-report driving discomfort and changed in driving	17 items (yes/no)	Driving-related discomfort significantly predicted SR among cognitive impaired drivers	1 + 1 + 1 = 3
Siren & Meng (2012)	Correlational (telephone interview)	888 drivers (75+)	Self-rated health and symptom checklist, self-rated cognitive and vision functioning, self-report driving skill and discomfort	17 items (yes/no)	Gender and health conditions predicted SR	2 + 1 + 1 = 4
Crizzle et al. (2013)	Cross-sectional case-control	26 drivers with PD 20 controls (age = 70+)	MoCA	SDA and SDF 20 item (yes/no) Objective GPS driving data	Self-estimate distance inaccurate for both groups Discrepancy more pronounced among PD drivers than controls PD drivers reported greater SR, but also drive more in reported situations	1 + 2 + 1 = 4
AQ2 Fraser et al. (2013)	Cross-sectional	99 drivers with bilateral cataract (age = 55+)	Visual acuity, contrast sensitivity, cognitive ability	DHQ (8 items; 1 "never" to 5 "always")	Drivers who report self-regulating at least one driving situation had significantly worst contrast sensitivity and increased depressive symptoms	1 + 1 + 1 = 3
Van Landingham et al. (2013)	Cross-sectional	139 drivers: 81 with glaucoma + 58 glaucoma suspect controls (age = 60–80)	Monocular visual acuities, pupillary dilation, cognitive ability	Salisbury Eye Evaluation Driving Study (SEEDS) questionnaire; 9 items (yes/no)	Glaucoma participants reported more driving limitations	1 + 1 + 1 = 3

Notes. AVLT = Auditory Verbal Learning Test; CDT = Clock Drawing Test; CESD = Center for Epidemiologic Studies Depression scale; DCS = Driving Comfort Scale; DHQ = Driving Habits Questionnaire; DSS = Digit Symbol Substitution; EPT = Everyday Problems Test; HPT = Hazard Perception Test; HVLTL = Hopkins Verbal Learning Test; MDSI = Multidimensional Driving Style Inventory; MMSE = Mini Mental State Examination; MoCA = Montreal Cognitive Assessment; MPFT = Multi-Point Focus Test; mVF-14 = modified Visual Function-14; MVPT = Motor-Free Visual Perception Test; PDA = Perceived Driving Abilities; OTDL = Observed Tasks of Daily Living; RBMT = Rivermead Behavioral Memory Test; SDA = Situational Driving Avoidance; SDF = Situational Driving Frequency; SR = self-regulation; UFOV = Useful Field Of View; SKILL card = Smith-Kettlewell Institute Low Luminance; TIADL = timed instrumental activities of daily living; TICS-M = The Modified Telephone Interview for Cognitive Status; WAIS-R = Wechsler Adult Intelligence Scale (revised).

^aOverall mean age of samples were reported whenever possible. Studies that used stratified age samples (e.g., Rimmó & Hakamies-Blomqvist, 2002) did not report overall mean age.

^bNaumann and coworkers (2011) examined self-regulation among drivers of all age groups (including older drivers). Samples were stratified by age and avoidance types. Age of overall sample and overall percentages of age groups were not provided.

^cGwyther and Holland (2012) examined self-regulation among drivers of all age groups.

specified, SR refers to self-reported SR of driving. This table also shows that 22 of the 29 studies (75.86%) were published between 2008 and 2013 (the numbers for 2013 are not for the full year because this search was performed in mid-2013), suggesting that there is growing interest in this topic and that an updated model that builds on this

new literature may be needed. Table 1 also shows that 7/29 (24.14%) studies received a quality rating of 3 (the lowest possible score) and the highest scoring study was rated 6 out of 7 ($n = 1, 3.45\%$). Some other notable features of these studies are that they typically adopt correlational study designs and focus on relatively few variables.

Establishing the Elements of an Evidence-Based Model

Table 1 shows that there are several categories of variable that have been studied in older adult driver SR studies, including sociodemographic variables, psychosocial variables, and health-related variables. The following section attempts to extract from this literature those variables that are relevant to the question of older adult driver SR and the nature of these relations.

Sociodemographic and Driving-Related Variables and SR

Table 1 shows that the proportion of older drivers who use SR typically increases with age. This finding appears robust; hence age was considered important to model. Most studies revealed a significant main effect of gender on SR, with women more likely to practice SR (and at a younger age) than men. Thus, gender too should be modeled. Correlational studies have revealed a negative association between distance driven and SR (Blanchard et al., 2010; Naumann, Dellinger, & Kresnow, 2011; Okonkwo, Crowe, Wadley, & Ball, 2008); however, the causality between annual driving distance and SR remains unexamined. A model that can account for driving distance appears warranted. There are potential cohort effects of age and gender on SR that could be mediated through variables such as health status or driving confidence, and although some of these relations have been suggested, they have not been systematically tested (e.g., Rimmó & Hakamies-Blomqvist, 2002; Vance et al., 2006). These variables have been examined independently and are discussed further in later sections. Studies typically report inconsistent relationships between other demographic variables and driving SR. These variables include prior crash involvement (Ball et al., 1998; Charlton et al. 2006; Okonkwo et al., 2008; Tuokko, McGee, Gabriel, & Rhodes, 2007), annual household income (Naumann et al., 2011; Ragland, Satariano, & MacLeod, 2004; West et al., 2003), spousal status (Charlton et al., 2006; Ragland et al., 2004), and employment status (Braitman & Williams, 2011). These variables were modeled to clarify their contribution.

Although sociodemographic variables such as annual driving distance may be described as individual-level factors, some of these variables can also be interpreted as environmental level factors. For example, this distance could be an individual matter of personal choice, or because the driver has limited access to public transportation. The importance of driving-specific environmental factors has been largely overlooked in the studies to date (Table 1). The social and economic determinants that support the use of SR, such as availability of public transport, road conditions, social networks that provide shared driving responsibilities (including other than spouse) some of which were included by Lindstrom-Forneri and coworkers (2010), are

logical extension of the evidence to date and were included in the model. The inclusion of these variables may also increase the international utility of the model.

Health, Medical Conditions, and SR

Visual function is the most commonly studied health-related variable in older adult driver SR studies (Table 1). The Useful Field of View (UFOV) test is the most commonly used measure of visual function and attention (Table 1: Ackerman et al., 2011; Ball et al., 1998; Molnar & Eby, 2008; O'Connor, Edwards, Wadley, & Crowe, 2010; Okonkwo et al., 2008; Ross et al., 2009; Vance et al., 2006), but self-report of visual function or impairment has also been used (e.g., Braitman & Williams, 2011; Charlton et al., 2006; Rimmó & Hakamies-Blomqvist, 2002; Ruechel & Mann, 2005; Sargent-Cox, Windsor, Walker, & Anstey, 2011; Siren & Meng, 2012; Windsor, Anstey, & Walker, 2008). A significant negative correlation between visual abilities (UFOV or self-report) and SR is typically demonstrated. Although visually impaired drivers were more likely than their non-impaired counterparts to report SR, a significant proportion of visually impaired drivers did not restrict their driving in difficult situations (e.g., Okonkwo et al., 2008; Ross et al., 2009). Thus, visual abilities should be modeled as a potential contributor to SR in older adult drivers.

Cognitive decline is also typically associated with increased SR (see Table 1: e.g., Ball et al., 1998; Vance et al., 2006; West et al., 2003); however, it is important to note that many studies exclude clinical groups, the measurement of cognition is highly variable, and the point at which cognitive factors become relevant remains unclear, suggesting that this factor should be modeled.

Studies of specific health conditions and "overall health" (assessed via self-report) also demonstrate a significant positive relation with SR (Braitman & Williams, 2011; D'Ambrosio, Donorfio, Coughlin, Mohyde, & Meyer, 2008; Kostyniuk & Molnar, 2008; O'Connor et al., 2010; Okonkwo et al., 2008; Ruechel & Mann, 2005; Sargent-Cox et al., 2011; Siren & Meng, 2012; Vance et al., 2006; West et al., 2003; Windsor et al., 2008). Other health conditions that were found to influence SR were stroke, arthritis, hearing impairment, restricted neck and trunk rotation, and pain in the limbs (Charlton et al., 2006; Ruechel & Mann, 2005; West et al., 2003). Further, the ability to acknowledge health conditions appears to be an important mediating factor (Okonkwo et al., 2008). It may be that older drivers' understanding of their health conditions, rather than their objective health status, influences SR. Therefore, clinical predictors appear important to SR but the bulk of studies use non-clinical groups, medical conditions will be modeled as a general factor (specific conditions will not be identified) and the model will be intended for a non-clinical audience.

Psychosocial Factors and SR

Nine (out of 29) studies investigated specific psychosocial variables that may underlie driving SR (e.g., Baldock et al., 2006; Charlton et al., 2006; Gwyther & Holland, 2012; Molnar & Eby, 2008; Windsor et al., 2008). Studies that used SR as an outcome measure demonstrate a significant association between older driver's insight into their functional abilities, their perceived driving abilities, driving confidence, and adoption of SR. Insight is most often defined as a cognitive factor or capacity that determines the level of understanding of one's impairment. This definition is common in the context of clinical environments, and we (Wong, Smith, & Sullivan, 2012), and others (e.g., MacDonald, Myers, & Blanchard, 2008), have defined it this way previously. In the broader context of driving choices, we now suggest that psychosocial inputs may also interact with this cognitive factor to determine an individual's understanding of their abilities. For example, Blanchard and coworkers (2010) reported that participants who reported lower driving-related comfort and lower perceived driving abilities reported reduced overall driving exposure, less night driving, and reduced radii of travel from home (i.e., distance of travel from home). Besides insight and perceived driving ability, Gwyther and Holland (2012) reported that affective attitude mediated the well-established positive relationship between age and SR. Baldock and coworkers (2006) reported that older drivers who reported greater perceived barriers in maintaining lifestyle reported lower levels of SR. This suggests that psychosocial factors such as driving confidence should be modeled.

Other psychosocial factors that have been described in the literature as relevant to older adults' health-related behavior, such as perceived behavioral control, instrumental attitude, and perceived barriers (WHO, 2002), have rarely been assessed in SR studies (Table 1). These latter factors are not explicit in the model by Anstey and coworkers (2005), but they are identified in the more recent model by Lindstrom-Forneri and coworkers (2010). On this basis, and although the evidence base from studies in this area is weak, it seems reasonable to propose that these additional factors be included in the model, given that they are well-established contributors to SR of other health behaviors (e.g., Rosenstock, 1966).

Integrating the Elements and the Need for Dynamic Relations

There is a clear need to integrate the factors associated with driving SR into a single framework or testable model that can account for dynamic interplay between the factors. It is evident from Table 1 that many studies have measured a limited set of potential predictors (e.g., Crizzle et al., 2013; D'Ambrosio et al., 2008; Gwyther & Holland, 2012; Horswill et al., 2011; Lotfipour et al., 2010; Meng, Siren, & Teasdale, 2013; Rimmó & Hakamies-Blomqvist, 2002; Sargent-Cox et al., 2011; Wong et al., 2012). The

failure to consider a comprehensive suite of variables makes it challenging to discern any systematic patterns of interaction between SR predictors, and it can skew the perceived significance of the variables studied. This problem is not solved with the existing models, which account for a relatively small number of factors (Anstey et al., 2005), or give weight to many factors but without describing, or allowing for, dynamic relations (Lindstrom-Forneri et al., 2010).

A related criticism of past studies is that several of them present bivariate correlations or odds ratios between predictors and SR without adequately adjusting for covariates (Table 1). Potential multicollinearity issues such as that between driving experience, age, number of medical conditions, gender, and confidence are not adequately addressed in most studies (e.g., Ball et al., 1998; Charlton et al., 2006; Kostyniuk & Molnar, 2008; Lotfipour et al., 2010; Naumann et al., 2011; Ruechel & Mann, 2005; Siren & Meng, 2012; Tuokko et al., 2007). These analytic techniques can neither identify potential interactions, nor more complex mechanistic pathways that reflect the often complex and dynamic nature of the factors involved in the aging process. There is a need to systematically examine interactions between factors to identify the mechanisms involved in older drivers' adoption of SR.

Toward The Multilevel Older Persons Transportation and Road Safety Model

To address the need for a dynamic model of older adult driver SR, which draws together factors identified from the systematic literature review and articulates a theoretical relation between those factors, we proposed the Multilevel Older Persons Transportation and Road Safety (MOTRS) model (Figure 2). This model is proposed as a hierarchical multilevel model, consisting of four levels: (a) Sociodemographic variables, (b) Driving-specific variables, (c) Psychosocial variables, and (d) Self-regulatory driving behaviors. Both sociodemographic and driving-specific variables represent factors at the individual and environmental level. Sociodemographic variables are encompassing factors that influence many aspects of older adults' daily living at both the individual (e.g., age, gender, health condition, cognitive and visual impairment, and financial income) and environmental levels (e.g., urban density, driving-specific social policies, societal attitudes toward driving, and social capital). Driving-specific variables are factors that specifically relate to older adults' and mobility more broadly. Examples of driving-specific factors at the individual level includes insight of driving abilities, driving experience, existing driving practices, and availability of driving partners. Driving-specific factors at the environmental level include availability of alternative transportation options, road conditions, and accessibility and proximity to amenities. Examples of the psychosocial factors in the model are

those based on the systematic review (e.g., driving confidence) and those drawn from the broad health behavior literature (e.g., perceived behavioral control, perceived barriers, instrumental attitude, and normative influence).

The central premise that underpins the MOTRS model is that both sociodemographic and driving-specific variables influence older adults driving SR through their psychosocial influences. The hierarchical structure of the model is consistent with findings that driving confidence and affective attitude account for the influence of age, and gender on SR. The mediational role of psychosocial variables is consistent with the broader health belief literature, which suggests that the subjective interpretation of environmental situations is a key determinant of a range of behavioral outcomes (e.g., Ajzen, 1991; Rosenstock, 1966). Further, the inclusion of social and environmental factors, such as the availability of alternative transport and degree of dependency on other drivers, represent the view that for older adults to self-regulate their driving, alternative social, and/or infrastructural support may be needed to satisfy their mobility needs.

The second assumption of the model is that each variable can simultaneously generate excitatory (i.e., positive) and inhibitory (i.e., negative) activation of the network.

This assumption draws on the dynamic framework provided by general connectionist models (Smith, 1996). Originating from cognitive psychology (McClelland & Rumelhart, 1986; Rogers & McClelland, 2004), the connectionist framework has been applied to a diverse range of social psychological areas due to its ability to account for the dynamic interactions between factors (e.g., Queller & Smith, 2002; van Overwalle, 2007). Connectionist models involve many simple processing units operating in parallel and affecting each other's activation through a network of weighted connections (Smith, 1996; Thomas & McClelland, 2008). Using the connectionist framework, the MOTRS model assumes that whether or not an older adult practices driving SR is determined by a combination of excitatory and inhibitory activation received in parallel from various sociodemographic and driving-specific factors, through their collective influence on their psychosocial variables. As an illustration (Figure 3), relocation to an urban area, at the sociodemographic factor level, could generate excitatory activation of factors at the driving-specific level, such as better road conditions and increased alternative transportation options. Simultaneously, the dislocation from existing social networks could generate inhibitory activation of

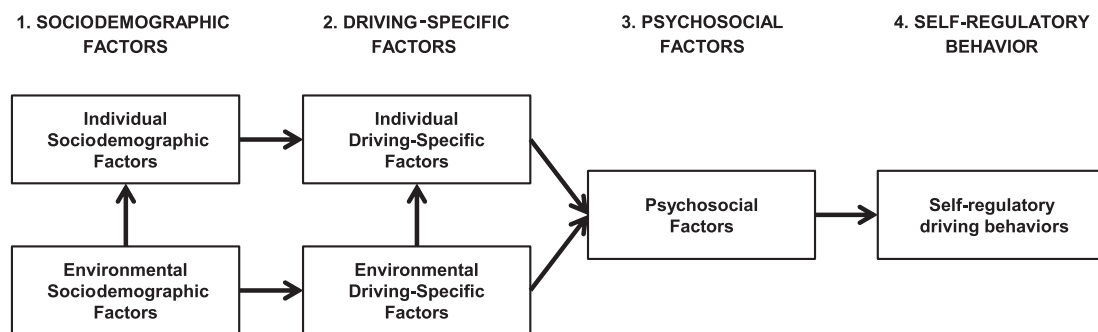


Figure 2. The Multilevel Older Person's Transportation and Road Safety Model.

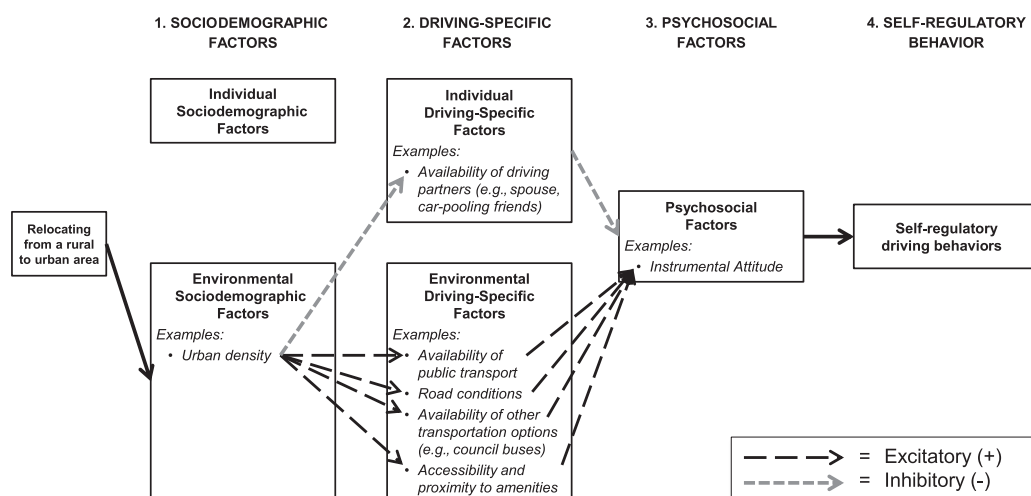


Figure 3. Example activation pattern of the Multilevel Older Persons Transportation and Road Safety model when the input of "relocation to urban rural" is added into the network.

factors, such as decreased availability of driving partners. These activations travel forward in the model, producing change in other variables such as instrumental or affective attitude to driving. As such, information is not necessarily put into the network in a sequential manner as occurs with the existing models; rather, input can be distributed to a number of components of the model at once, in a parallel and simultaneous manner. This parallel distribution may be necessary to account for the complex interactions occurring in the older driver context, particularly mediating and moderating relationships between factors described in the current literature.

The final two assumptions of the MOTRS model relate to the process of learning. There is abundant behavioral and neurological evidence that humans are capable of lifelong learning, more importantly, relearning over time. Most current driver behavior models, and traditional health behavior models, are based on unidirectional causal pathways (Smith, 1996, 2009). The lack of an explicit mechanism for updating existing decision pathways implies that attitudes and beliefs are fixed and are resistant to change. Although attitudes can influence behavior through a bottom-up processing, behavior can also cause changes in beliefs and attitudes through top-down processing. An example within the older driver context is that a “near-miss” could influence the driver to reconsider their beliefs about their driving; or, the use of SR in face of increased functional impairment could occur because of adaptive learning. Thus, the fixed nature of existing models represents a significant limitation; they cannot readily account for changes in older adult drivers’ use of SR. The MOTRS model accommodates adaptive learning through the use of bidirectional causal pathways, particularly involving modifiable psychosocial factors. For example, a driving error such as a “near-miss” collision can be noted and flow back through the network, providing information on how the weighting of pathways should be changed—a process referred to as back propagation (e.g., a reduction Perceived Behavioral Control such as “maybe I am not controlling the vehicle as well as I thought I was”). Consistent with the notion that attitudes and beliefs can be modified through behavior, when compared with current older drivers, older ex-drivers reported more positive attitudes toward driving cessation (Edwards et al., 2009). This change in attitudes following driving cessation demonstrates the dynamic interaction between behaviors and attitudes that the MOTRS model attempts to capture.

The final assumption relates to another aspect of learning: incremental learning. Within the MOTRS model, the recency and frequency with which a pathway has been activated influences the ease and speed of subsequent activation when elicited by similar cues, sometimes at the expense of other unrelated pathways. For example, as a result of a recent relocation to an urban area, a pathway between the availability of alternative transport and instrumental attitude of vehicle, SR could be activated. The frequent access of this pathway via increased use of public transport would

strengthen this pathway, thereby increasing its weighting. This learning process might be to the detriment of other, less used pathways, such as the connection between availability of driving partners, instrumental attitude, and SR. Put simply, over time, the availability of alternative transport may become a stronger predictor of SR than might the availability of driving partners. This novel prediction, based on the importance of recent and frequent exposure, is common in cognitive models but is not intrinsic to most theoretical frameworks within the transportation, aging, and social psychology literature. Perhaps because they are often developed using information from cross-sectional surveys, traditional transportation and aging models are based on unidirectional causal pathways (Smith, 1996, 2009). Using methods such as longitudinal modeling and computational modeling (e.g., Ferrer & McArdle, 2010; MacCallum & Austin, 2000), assumptions regarding older adults’ learning behaviors in SR can be empirically tested.

Practical and Research Implications

Neither of the existing older driver safety models (Anstey et al., 2005; Lindstrom-Forneri, Tuokko, & Rhodes, 2007) focus on driving SR, which is an important precursor to driving cessation and a behavior that holds promise as a point of intervention for improving the safety and extending the functional mobility of older adults (Dickerson et al., 2007). These previous models were intended to describe different targets; therefore, some differences are to be expected. For the purposes of describing older adult driving SR, however, we suggest that previous models have not adequately considered the influence of psychological and social factors, nor illustrated the dynamic interactions between these constructs in an empirically testable manner. The Transportation and Aging Interest Group of the Gerontological Society of America has identified that there is a critical need for a theoretical model that considers the driver, the environment, and the interaction between the two, as well as self-beliefs and societal influences (Dickerson et al., 2007); the MOTRS model meets these requirements and may help to address this gap.

The MOTRS model is the first older adult driver SR model to integrate the factors and assumptions identified from a systematic literature review, with factors that have been found to be important predictors of SR and health behaviors generally. This combination means that the model is composed of factors that are comparatively well understood in the driving context such as age, gender, and visual impairments and factors that are well established in other contexts but require further investigation in driving research (such as environmental and psychosocial factors). The MOTRS model allows the generation of specific and testable pathways about the dynamic interactions of factors. If supported by data, the model could also be used as a framework for developing and evaluating interventions to improve the safety and mobility of

older adults. For example, a prediction of the model is that to improve the use of SR, effective interventions need to not only address specific variables (e.g., awareness of health conditions) but also consider other individual, environmental determinants, and psychosocial factors of the individual.

Given the lack of investigation on the psychosocial factors that underlie SR, it is likely that the current systematic review has not identified all important psychosocial variables in the process of SR. Future research should consider variables such as self-efficacy and sense of mastery, which have been documented psychosocial determinants of driving and health-related behaviors (Bandura, 2004; Schwarzer, 1992). The influence of factors related to personality such as impulsivity, sensation seeking, and conscientiousness should also be explored. Ideally, the exploration of these and other related variables could occur in the context of a comprehensive evaluation of the full model.

The limitations of this model and review are that we only used published peer-reviewed studies identified using specific databases and search terms. This strategy risks omitting some studies or findings, and in particular, we did not include research published in languages other than English. Technical, government and internal reports, non-peer reviewed articles, and conference abstracts (i.e., sometimes referred to as the “grey literature”) were also not reviewed, and there is a risk of publication bias. Further, the quality metric, while established is not widely used and relies on a few selected parameters. For inclusivity, we also allowed variation in the definition of SR of reviewed studies. Different variables may have been modeled if these methodological considerations had been actioned otherwise; however, the intent of this article was to generate an exploratory model based on a defined review process, and this model should be regarded as tentative until empirically tested.

Conclusion

A mismatch between the use of SR and older adults' driving ability has been reported in a number of studies (e.g., Baldock et al., 2006; Charlton et al., 2006; Cushman, 1996; Marottoli & Richardson, 1998; Sullivan et al., 2011). These studies report that while some older adults are aware of their functional abilities and self-regulate their driving accordingly; overall, SR is not associated reliably with driving performance as assessed by simulated and on-road driving performance. The MOTRS model could assist in unpacking these complex relationships. It may help to identify if and when driving SR is useful and the extent to which it may play a role in improving and sustaining older adult mobility.

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References

- Ackerman, M. L., Crowe, M., Vance, D. E., Wadley, V. G., Owsley, C., & Ball, K. K. (2011). The impact of feedback on self-rated driving ability and driving self-regulation among older adults. *The Gerontologist*, *51*, 367–378. doi:10.1093/geront/gnq082
- Ajzen, I. (1991). The theory of planned behaviour. *Organizational Behavior and Human Decision Processes*, *50*, 178–211. doi:10.1016/0749-5978(91)90020-T
- Anstey, K. J., Wood, J., Lord, S., & Walker, J. G. (2005). Cognitive, sensory and physical factors enabling driving safety in older adults. *Clinical Psychology Review*, *25*, 45–65. doi:10.1016/j.cpr.2004.07.008
- Baldock, M. R. J., Mathias, J. L., McLean, A. J., & Berndt, A. (2006). Self-regulation of driving and its relationship to driving ability among older adults. *Accident Analysis and Prevention*, *38*, 1038–1045. doi:10.1016/j.aap.2006.04.016
- Ball, K., Owsley, C., Stalvey, B., Roenker, D. L., Sloane, M. E., & Graves, M. (1998). Driving avoidance and functional impairment in older drivers. *Accident Analysis and Prevention*, *30*, 313–322. doi:10.1016/S0001-4575(97)00102-4
- Bandura, A. (2004). Health promotion by social cognitive means. *Health Education & Behavior*, *31*, 31–143. doi:10.1177/1090198104263660
- Blanchard, R. A., Myers, A. M., & Porter, M. M. (2010). Correspondence between self-reported and objective measures of driving exposure and patterns in older drivers. *Accident Analysis and Prevention*, *42*, 523–529. doi:10.1016/j.aap.2009.09.018
- Braitman, K. A., & McCartt, A. T. (2008). Characteristics of older drivers who self-limit their driving. *Annual proceedings/ Association for the Advancement of Automotive Medicine. Association for the Advancement of Automotive Medicine*, *52*, 245–254.
- Braitman, K. A., & Williams, A. F. (2011). Changes in self-regulatory driving among older drivers over time. *Traffic Injury Prevention*, *12*, 568–575. doi:10.1080/15389588.2011.616249
- Charlton, J. L., Oxley, J., Fildes, B., Oxley, P., Newstead, S., Koppel, S., & Ohare, M. (2006). Characteristics of older drivers who adopt self-regulatory driving behaviours. *Transportation Research Part F: Traffic Psychology and Behaviour*, *9*, 363–373. doi:10.1016/j.trf.2006.06.006
- Crizzle, A. M., & Myers, A. M. (2013). Examination of naturalistic driving practices in drivers with Parkinson's disease compared to age and gender-matched controls. *Accident Analysis and Prevention*, *50*, 724–731. doi:10.1016/j.aap.2012.06.025
- Cushman, L. A. (1996). Cognitive capacity and concurrent driving performance in older drivers. *IATSS Research*, *20*, 38–45.
- D'Ambrosio, L. A., Donorfio, L. K. M., Coughlin, J. F., Mohyde, M., & Meyer, J. (2008). Gender differences in self-regulation patterns and attitudes toward driving among older adults. *Journal of Women and Aging*, *20*, 265–282. doi:10.1080/08952840801984758
- Dickerson, A. E., Molnar, L. J., Eby, D. W., Adler, G., Bedard, M., Berg-Weger, M., ... Trujillo, L. (2007). Transportation and aging:

- A research agenda for advancing safe mobility. *Gerontologist*, 47, 578–590. doi:10.1093/geront/47.5.578
- Donorfio, L. K. M., D'Ambrosio, L. A., Coughlin, J. F., & Mohyde, M. (2009). To drive or not to drive, that isn't the question—The meaning of self-regulation among older drivers. *Journal of Safety Research*, 40, 221–226. doi:10.1016/j.jsr.2009.04.002
- Edwards, J. D., Delahunt, P. B., & Mahncke, H. W. (2009). Cognitive speed of processing training delays driving cessation. *Journals of Gerontology Series A-Biological Sciences and Medical Sciences*, 64, 1262–1267.
- Ferrer, E., & McArdle, J. J. (2010). Longitudinal modeling of developmental changes in psychological research. *Current Directions in Psychological Science*, 19, 149–154. doi:10.1177/0963721410370300
- Fraser, M. L., Meuleners, L. B., Ng, J. Q., and Morlet, N. (2013). Driver self-regulation and depressive symptoms in cataract patients awaiting surgery: A cross-sectional study. *BMC Ophthalmol*, 13, 45.
- Gwyther, H., & Holland, C. (2012). The effect of age, gender and attitudes on self-regulation in driving. *Accident Analysis and Prevention*, 45, 19–28. doi:10.1016/j.aap.2011.11.022
- Hakamies-Blomqvist, L., & Wahlstrom, B. (1998). Why do older drivers give up driving? *Accident Analysis and Prevention*, 30, 305–312. doi:10.1016/S0001-4575(97)00106-1
- Hallgren, K. A. (2012). Computing inter-rater reliability for observational data: An overview and tutorial. *Tutorials in Quantitative Methods for Psychology*, 8, 23–34.
- Horswill, M. S., Anstey, K. J., Hatherly, C., Wood, J. M., & Pachana, N. A. (2011). Older drivers' insight into their hazard perception ability. *Accident Analysis and Prevention*, 43, 2121–2127. doi:10.1016/j.aap.2011.05.035
- Kostyniuk, L. P., & Molnar, L. J. (2008). Self-regulatory driving practices among older adults: Health, age and sex effects. *Accident Analysis and Prevention*, 40, 1576–1580. doi:10.1016/j.aap.2008.04.005
- Lindstrom-Forneri, W., Tuokko, H. A., Garrett, D., & Molnar, F. (2010). Driving as an everyday competence: A model of driving competence and behavior. *Clinical Gerontologist*, 33, 283–297. doi:10.1080/07317115.2010.502106
- Lindstrom-Forneri, W., Tuokko, H. A., & Rhodes, R. E. (2007). "Getting Around Town": A preliminary investigation of the theory of planned behaviour and intent to change driving behaviors among older adults. *Journal of Applied Gerontology*, 26, 385–398. doi:10.1177/0733464807304573
- Lotfipour, S., Patel, B. H., Grotzky, T. A., Anderson, C. L., Carr, E. M., Ahmed, S. S., ... Vaca, F. E. (2010). Comparison of the visual function index to the Snellen visual acuity test in predicting older adult self-restricted driving. *Traffic Injury Prevention*, 11, 503–507. doi:10.1080/15389588.2010.488494
- MacCallum, R. C., & Austin, J. T. (2000). Applications of structural equation modeling in psychological research. *Annual Review of Psychology*, 51, 201–226. doi:10.1146/annurev.psych.51.1.201
- MacDonald, L., Myers, A. M., & Blanchard, R. A. (2008). Correspondence among older drivers' perceptions, abilities, and behaviors. *Topics in Geriatric Rehabilitation*, 24, 239–252. doi:10.1097/01.TGR.0000333756.75303.b9
- Marottoli, R., & Richardson, E. (1998). Confidence in, and self-rating of, driving ability among older drivers. *Accident Analysis and Prevention*, 30, 331–336. doi:10.1016/S0001-4575(97)00100-0
- McClelland, J. L., Rumelhart, D. E., & The PDP Research Group. (1986). *Part II cognitive modelling paradigms*. In D. E. Rumelhart (Ed.), *Parallel distributed processing: Explorations in the microstructure of cognition* (Vol. II). Cambridge, MA: MIT Press.
- Meng, A., Siren, A., & Teasdale, T. W. (2013). Older drivers with cognitive impairment: Perceived changes in driving skills, driving-related discomfort and self-regulation of driving. *European Geriatric Medicine*, 4, 154–160. doi:10.1016/j.eurger.2013.01.002
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & The PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *Annals of Internal Medicine*, 151, 264–269. doi:10.7326/0003-4819-151-4-200908180-00135
- Molnar, L. J., & Eby, D. W. (2008). The relationship between self-regulation and driving-related abilities in older drivers: An exploratory study. *Traffic Injury Prevention*, 9, 314–319. doi:10.1080/15389580801895319
- Myers, A. M., Paradis, J. A., & Blanchard, R. A. (2008). Conceptualizing and measuring confidence in older drivers: Development of the day and night driving comfort scales. *Archives of Physical Medicine and Rehabilitation*, 89, 630–640. doi:10.1016/j.apmr.2007.09.037
- Naumann, R. B., Dellinger, A. M., & Kresnow, M. J. (2011). Driving self-restriction in high-risk conditions: How do older drivers compare to others? *Journal of Safety Research*, 42, 67–71. doi:10.1016/j.jsr.2010.12.001
- O'Connor, M. L., Edwards, J. D., Wadley, V. G., & Crowe, M. (2010). Changes in mobility among older adults with psychometrically defined mild cognitive impairment. *Journals of Gerontology Series B-Psychological Sciences and Social Sciences*, 65, 306–316. doi:10.1093/geronb/gbq003
- Okonkwo, O. C., Crowe, M., Wadley, V. G., & Ball, K. (2008). Visual attention and self-regulation of driving among older adults. *International Psychogeriatrics*, 20, 162–173. doi:http://dx.doi.org/10.1017/S104161020700539X
- Organisation for Economic Co-operation and Development. (2009). *Ageing societies, in OECD Factbook 2009: Economic, environmental and social statistics*, OECD Publishing. doi:10.1787/18147364
- Queller, S., & Smith, E. R. (2002). Subtyping versus bookkeeping in stereotype learning and change: Connectionist simulations and empirical findings. *Journal of Personality and Social Psychology*, 82, 300–313. doi:10.1037/0022-3514.82.3.300
- Ragland, D. R., Satariano, W. A., & MacLeod, K. E. (2004). Reasons given by older people for limitation or avoidance of driving. *The Gerontologist*, 44, 237–244. doi:10.1093/geront/44.2.237
- Rimmó, P.-A., & Hakamies-Blomqvist, L. (2002). Older drivers' aberrant driving behaviour, impaired activity, and health as reasons for self-imposed driving limitations. *Transportation Research Part F: Traffic Psychology and Behaviour*, 5, 47–62. doi:10.1016/S1369-8478(02)00005-0
- Rogers, T. T., & McClelland, J. L. (2004). *Semantic cognition: A parallel distributed processing approach*. Cambridge, MA: MIT Press.
- Rosenstock, I. M. (1966). Why people use health services. *Milbank Memorial Fund Quarterly*, 44, 94–127. doi:10.2307/3348967
- Ross, L. A., Anstey, K., Kiely, K. M., Windsor, T., Byles, J., Luszcz, M., ... Joyce, J. J. (2009). Older Australian

- drivers: Predictors. Cognitive and visual impairment, and international comparisons. *The Gerontologist*, **49**(Suppl. 2), 226. doi:10.1111/j.1532-5415.2009.02439.x
- Ruechel, S., & Mann, W. C. (2005). Self-regulation of driving by older persons. *Physical & Occupational Therapy in Geriatrics*, **23**, 91–101. doi:10.1300/J147v23n02_06
- Sargent-Cox, K. A., Windsor, T., Walker, J., & Anstey, K. J. (2011). Health literacy of older drivers and the importance of health experience for self-regulation of driving behaviour. *Accident Analysis and Prevention*, **43**, 898–905. doi:10.1016/j.aap.2010.11.012
- Schwarzer, R. (1992). Self-efficacy in the adoption and maintenance of health behaviours: Theoretical approaches and a new model. In R. Schwarzer (Ed.), *Self-efficacy: Though control of action* (pp. 217–243). Washington, DC: Hemisphere Publishing.
- Siren, A., & Meng, A. (2012). Cognitive screening of older drivers does not produce safety benefits. *Accident Analysis and Prevention*, **45**, 634–638. doi:10.1016/j.aap.2011.09.032
- Smith, E. R. (1996). What do connectionism and social psychology offer each other? *Journal of Personality and Social Psychology*, **70**, 893–912. doi:10.1037/0022-3514.70.5.893
- Smith, E. R. (2009). Distributed connectionist models in social psychology. *Social and Personality Psychology Compass*, **3**, 64–79. doi:10.1111/j.1751-9004.2008.00160.x
- Stalvey, B., & Owsley, C. (2000). Self-perceptions and current practices of high-risk older drivers: Implications for driver safety interventions. *Journal of Health Psychology*, **5**, 441–456. doi:10.1177/135910530000500404
- Sullivan, K. A., Smith, S. S., Horswill, M. S., & Lurie-Beck, J. K. (2011). Older adults' safety perceptions of driving situations: Towards a new driving self-regulation scale. *Accident Analysis and Prevention*, **43**, 1003–1009. doi:10.1016/j.aap.2010.11.031
- Thomas, M. S. C., & McClelland, J. L. (2008). Connectionist models of cognition. In R. Sun (Ed.), *The Cambridge handbook of computational psychology* (pp. 23–58). New York, NY: Cambridge University Press. doi:10.1017/CBO9780511816772.005
- Tuokko, H. A., McGee, P., Gabriel, G., & Rhodes, R. E. (2007). Perception, attitudes and beliefs, and openness to change: Implications for older driver education. *Accident Analysis and Prevention*, **39**, 812–817. doi:10.1016/j.aap.2006.12.002
- Vance, D. E., Roenker, D. L., Cissell, G. M., Edwards, J. D., Wadley, V. G., & Ball, K. K. (2006). Predictors of driving exposure and avoidance in a field study of older drivers from the state of Maryland. *Accident Analysis and Prevention*, **38**, 823–831. doi:10.1016/j.aap.2006.02.008
- van Landingham, S. W., et al. et al. (2013). Driving patterns in older adults with glaucoma. *BMC Ophthalmology*, **13**, 4.
- van Overwalle, F. (2007). *Social connectionism*. New York, NY: Psychology Press.
- West, C. G., Gildengorin, G., Haegerstrom-Portnoy, G., Lott, L. A., Schneck, M. E., & Brabyn, J. A. (2003). Vision and driving self-restriction in older adults. *Journal of the American Geriatrics Society*, **51**, 1348–1355. doi:10.1046/j.1532-5415.2003.51482.x
- Windsor, T. D., Anstey, K. J., & Walker, J. G. (2008). Ability perceptions, perceived control, and risk avoidance among male and female older drivers. *The Journals of Gerontology: Series B: Psychological Sciences and Social Sciences*, **63B**, P75–P83. doi:10.1093/geronb/63.2.P75
- Wong, I., Smith, S., & Sullivan, K. A. (2012). The relationship between cognitive ability, insight and self-regulatory behaviors: Findings from the older driver population. *Accident, Analysis and Prevention*, **49**, 316–321. doi:10.1016/j.aap.2012.05.031
- World Health Organization. (2002). *Active ageing: A policy framework*. Geneva, Switzerland: World Health Organization.
- Wright, R. W., Brand, R. A., Dunn, W., & Spindler, K. P. (2007). How to write a systematic review. *Clinical Orthopaedics and Related Research*, **455**, 23–29. doi:10.1097/BLO.0b013e31802c9098