Sheridan College
SOURCE: Sheridan Scholarly Output Undergraduate Research Creative Excellence

Centre Publications and Scholarship | Sheridan Centre for Elder Research

9-2005

Sign Comprehension in Young Adults, the Healthy Elderly, and Older People with Varying Levels of Cognitive Impairment - Report Series # 5

Pat Spadafora
Sheridan College, pat.spadafora@sheridancollege.ca

C.T. (Chip) Scialfa
University of Calgary

Marianne Klein
Sheridan College

Agata Lesnik
Sheridan College

Antje Heinrich
University of Toronto

See next page for additional authors

Authors
Pat Spadafora, C.T. (Chip) Scialfa, Marianne Klein, Agata Lesnik, Antje Heinrich, and Magda Lenartowicz

Report Series - # 5

Sign Comprehension in Young Adults, the Healthy Elderly, and Older People with Varying Levels of Cognitive Impairment

Project Team

Dr. C.T. (Chip) Scialfa	*University of Calgary*
Pat Spadafora (Director)	*Sheridan Elder Research Centre (SERC)*
Marianne Klein & Agata Lesnik	*Sheridan Social Service Worker-Gerontology Program, SERC Research Assistants*
Antje Heinrich	*University of Toronto at Mississauga (UTM)*
Magda Lenartowicz	*SERC Research Assistant*

About SERC (Sheridan Elder Research Centre)

Through applied research the Sheridan Elder Research Centre (SERC) will identify, develop, test and support implementation of innovative strategies that improve the quality of life for older adults and their families.

1. Wherever possible, older adults participate in the identification of research questions and contribute to the development of research projects at SERC.
2. We conduct applied research from a psychosocial perspective which builds on the strengths of older adults.
3. Our research is intended to directly benefit older adults and their families in their everyday lives. The process of knowledge translation takes our research findings from lab to life.
4. SERC affiliated researchers disseminate research findings to a range of stakeholders through the SERC Research Report Series, research forums, educational events and other means.
5. A multigenerational approach is implicit, and frequently explicit, in our research.
6. To the extent possible our research is linked to and complements academic programs at the Sheridan College Institute of Technology and Advanced Learning.

EXAMPLES OF SERC RESEARCH

The Built Environment	**Information & Communication Technology** (ICT)	**Human Communication**	**Public Policy**	**Other research interests**
- Indoor/Outdoor Design - Graphic Design	- Accessible computing - Age appropriate games	- Hearing/low vision - Vision - Language	- Elder Abuse - Ageism	- Self image/self esteem - Care-giver support

Contact Information:

Pat Spadafora, Director, Sheridan Elder Research Centre
Sheridan Institute of Technology and Advanced Learning
1430 Trafalgar Road, Oakville, ON L6H 2L1
Tel: (905) 845-9430 ext. 8615, Fax: (905) 815-4230
Email: pat.spadafora@sheridaninstitute.ca

Table of Contents

This study, conducted in the fall of 2004 and the winter of 2005, sought to determine whether sign comprehension suffers in healthy aging and in the presence of cognitive impairment. Sign comprehension is critical for effective driving, response to warnings and way-finding. If signs are poorly comprehended by older people including those with cognitive impairment, accident risk will be increased and independence may be compromised. Groups of young adults, healthy older adults and older adults with varying levels of cognitive impairment were asked the meaning of 65 signs used for driving, warning and way-finding. Healthy older adults were generally good at sign comprehension, but had some difficulty with way-finding signs. Older adults with cognitive impairments had poorer sign comprehension overall and were particularly poor with way-finding signage. Testing of sign comprehension needs to involve a more heterogeneous sampling of older adults. As well, signs that include text would be beneficial to those with cognitive impairment.

1. Purpose

Increasingly, information that provides warnings, assists in navigation, and signals the need for behavioral control comes in graphical form, either replacing or supplementing text. The use of such graphical devices has been common in the control and regulation of driving behavior (Moeur, online) and is becoming more common as a means of facilitating way-finding in hospitals, airports, shopping centers, etc. “Icons” are used to indicate available services (e.g., hotels, information kiosks) and are common in technologies like browsers for the World Wide Web, Intelligent Vehicular Systems and household appliances.

A substantial literature on the efficacy of icons exists in transportation. As a result, regulatory agencies mandate standardized graphic elements of specific sizes, made of specific materials like retro-reflective surfaces that achieve greatest effectiveness (U.S. DOT, 2001). Comparing icons to text-only signs, research has demonstrated that icons can often be seen more easily at greater distances and under poorer viewing conditions (Day, 1988; Kline & Fuchs, 1993; Kline, Ghali, Kline, & Brown, 1990). Hence, these results indicate that icons are important for driving, an importance that is underscored by the fact that many jurisdictions provide extensive treatment of the meaning of signs in the training manuals distributed to would-be drivers. (e.g., http://www.drivershandbook.com/).

Despite the burgeoning use of graphical signage today, little is known about the effectiveness of the symbols and the extent to which they place information-processing burdens on users. The time taken to comprehend the meaning of a poorly chosen icon can slow task performance, create a risk of errors and increase frustration with new technologies (Morrow, Leirer, & Andrassy, 1996; Wolf & Wogalter, 1993). This may be particularly true in older individuals who, because of perceptual and cognitive deficits, take more time to encode and retrieve the meaning of icons (Craik & Simon, 1980). The purpose of the present study was to determine if comprehension of signage, often iconic in nature, is related to age and to extend this research to elders who are manifesting some cognitive impairment.

1.1 Sign Comprehension in Older Adults
Al-Madani & Al-Janahi (2002) demonstrated that a heterogeneous participant group can potentially decrease comprehension performance of icons. They reported the results of a study carried out in five mid-eastern countries wherein observers, on average, recognized fewer than 60% of the traffic signs presented to them. While one might argue that this reflects the lack of experience with specific signs amongst those sampled, increasing user heterogeneity will create similar conditions in many domains and locations where icons are being used.

Age is certainly one variable that contributes to the variability of the user population. For example, because developed countries can expect an increase in the number of aging drivers and the average age of these drivers, it is important to determine if signage used on the roadway are as readily comprehended by older adults as they are by the young adults. Similar arguments can be made in other environments where graphical signage is frequently used.

There are many reasons that older adults have more difficulty comprehending the meaning of signs. Age-related reductions in acuity and contrast sensitivity (see Kline & Scialfa, 1997; Schneider & Pichora-Fuller, 2000) can degrade recognition (Higgins, Wood, & Tait, 1998; Kline, et al, 1990) and this is particularly true if critical elements of the sign, text or iconic, are of higher spatial frequency or reduced luminance (Sivak & Olson, 1982). It is not surprising then, that the literature indicates older individuals require closer viewing distances to see icons (Kline & Fuchs, 1993 Kline, et al., 1990). In addition to sensory factors, older adults may have more difficulty with sign comprehension because they are less familiar with them or cannot retrieve their meaning. Familiarity is an issue in emerging technologies that are adopted by the elderly later than by younger consumers (Willis, 2004). Age deficits in memory are well-documented (Craik, 1977) and are exacerbated in many age-related dementias including Alzheimer's disease and related dementias (ADRDs) (Crowell, Luis, Vanderploeg, Schinka, & Mullan, 2002). For these and other reasons, there is specific treatment of sign design for older people in publications like the U.S. Department of Transportation's, *Older Driver Highway Design Handbook* (US DOT, 1998).

Although there are many reasons why older adults should have more difficulty comprehending the meaning of iconic signs, the literature is by no means clear-cut on this issue, a result that may, at least in part, be related to the test used to assess sign comprehension. The cognitive aging literature provides substantial evidence that age differences in performance are reduced when recognition tests are used (see Craik, 1977). For example, Al-Madani & Al-Janahi (2002) using a recognition test found no association between age and performance.

We may expect to find clearer age differences when recall is required. In this vein, Kline & Fuchs (1993) presented icons and text signs to young and older adults and asked them to recall the meaning of traffic signs. They found that visibility distance was greater for icons than for text signs and this was true for both younger and older observers. Against expectation, no age differences in comprehension were observed for either iconic or text signs. However, because comprehension responses were not made until after the sign was visible, it is not clear if text or iconic signs were comprehended at different distances and if this was related to age. As well, because only four common traffic signs (e.g., Divided Highway) were used there is reason to question if these results extend to other signs that may be less common

Other studies have found the predicted age differences. For instance, Stutts, Stewart and Martell (1998) asked their participants to provide the meaning of 12 signs based on color and shape information and examined the relationships between crash rate and several measures of cognitive ability, including the North Carolina Traffic Sign Recognition Test. Their analyses indicated that sign perception decreased significantly with increasing age.

One of the more ambitious studies in this area was carried out by Dewar, Kline and Swanson (1996). They examined comprehension of all 85 non-text signs in the U.S. *Manual on Uniform Traffic Control Devices for Streets and Highways* (FHWA, U.S. DOT, 1988) in a life-span adult sample of drivers. The older drivers, in this case over the age of 60 yrs, had poorer comprehension on 39% of the signs. Similar age deficits have been reported in dynamic viewing conditions (Hulbert , Beers & Fowler, 1979) and simulated driving tasks (Allen, Parseghain & Van Valkenburg, 1980).

Halpern (1984) asked younger and older people to read a traffic message aloud and then to indicate if a regulatory or warning sign matched the message. While younger adults showed no difference in reaction time to verbal or iconic signs, the older people responded more quickly to text signs. This study had the advantage of assessing the recognition of a sign's meaning, which is critical to responding appropriately. Additionally, by measuring latency, it reflected an aspect of behavior that is important for timed tasks like driving or responding to warnings. A potential disadvantage to the methods employed was that the presentation of every target message may have primed people to respond to text. If this was more likely among older adults, the text advantage may not generalize to real-world settings.

Although most studies concerned with sign comprehension have used traffic signs, there are a few studies that have examined signs in other domains. Yet, the effect of age on sign comprehension is still unclear. Hancock, Rogers, Schroeder & Fisk (2004) compared younger and older adults' comprehension of symbol signs that served to provide hazard alerts, indicate mandatory action (e.g., wear ear protection), prohibit actions (e.g., no smoking) or provide information (e.g., first aid). They found that older adults' comprehension was lower than that of the young and that familiarity led to better comprehension. Examining the use of icons to improve comprehension of information related to prescription medications, Morrell, Park and Poon (1990) reported negative age effects; that is adding icons improved younger adults performance for medication information but reduced recall in older adults. In contrast, Morrow et al. (1998), found that adding iconic time-line information to text resulted in reduced study time and improved recall equally for younger and older adults.

1.2 Sign Comprehension and Cognitive Impairment
If the literature on comprehension of signs among the healthy aged is a bit murky, then sign comprehension in special older populations is even more of an unknown. Particularly for those with cognitive impairment, comprehension of icons might be compromised because of a failure to retrieve information about prior experience with the icon itself. Failures at understanding might also arise because of problems in linking the icon to its referent or with difficulties retrieving the icon's name. As semantic memory is relatively unaffected in the early stages of dementing diseases, it is possible that text signs are more effective than icons for people suffering from Alzheimer's Disease and Related Dementias (ADRD) and similar health problems.

Carr, LaBarge, Dunniggan and Storandt (1998) found that those with mild or moderate ADRD could be discriminated from healthy, like-aged adults using a 10-item Traffic Sign Naming Test. In a dramatic example of this problem, Mitchell, Castleden and Fantthome (1995) assessed cognitive function in a group of older people, some of whom were cognitively healthy and others who had probable ADRD. Every member of the ADRD group failed a test of road sign recognition, even though 68% of them were still driving. Similarly, Brashear, et al (1998) used their Traffic Sign Recognition Test to compare healthy older adults and those with ADRD. Drivers with dementia identified only 6 of 10 common traffic signs and 24% failed to identify the "STOP" sign correctly. If recognition of common traffic signs is problematic, then what chance has the person with ADRD to recognize less familiar signs that they might encounter in the home, hospital, care facility or general surroundings?

The present study examined sign comprehension for a wide range of signs related to driving, navigation, et cetera in a heterogeneous sample of participants. We compared comprehension in young and healthy older adults as well as those suffering from mild to moderate degrees of cognitive impairment. Moreover, we examined the relationship between comprehension and the ability to carry out tasks of daily living.

2. Methodology

2.1 Respondent Sampling
Twenty participants were tested in each of four groups; young healthy adults, healthy elders, elders with early stage dementia, and elders with moderate to severe cognitive impairment. The cognitive impairment could be a result of physician-diagnosed probable ADRD, Parkinson's disease or multi-infarct dementia. In all cases, ADRD was diagnosed. Additionally, four participants had been diagnosed with more than one impairment.

The young and the healthy older adults were community-dwelling citizens of Mississauga and Oakville, Ontario (Canada). The participants with early stage dementia were recruited through the Ottawa branch of the Alzheimer Society. Moderately to severely impaired individuals were participants in the Seniors Day Program operated by the Victoria Order of Nurses (VON), Halton Branch at the Sheridan Elder Research Centre on the campus of the Sheridan Institute of Technology and Advanced Learning. The participants from the day program volunteered their time and efforts, but all other participants received $20 (CDN) each for participation.

2.1.1 Demographic and Medical Data
For each individual, demographic and medical information was collected by means of several questionnaires. Young and healthy older adults provided the information at the beginning of the testing session, while for impaired older adults the information was collected from their medical files.

Demographic data included information on age, years of education after high school, perceived health, and activity level. Subjective health information was gathered by asking participants to rate their physical health on a scale from 1 (very poor) to 5 (excellent). Information on the ability to carry out independent activities of daily living was collected by means of the Lawton Instrumental Activities of Daily Living Scale (Lawton & Brody, 1969). The Standardized Mini Mental State Exam (SMMSE, Molloy, 1999) provided information on the level of cognitive functioning. Lastly, before the start of the testing session, we measured corrected Snellen visual acuity at a 3 m viewing distance.

2.2. Method
Sixty-five signs were chosen to represent four domains of symbols: regulatory driving (18 signs), driving warnings (9 signs), other warning signs (10 signs), and way finding signs (28 signs). A complete list of signs is presented in Table 4. The signs were taken from a variety of web sources.

2.3 Data Collection Methods
The signs were presented sequentially using a standard PC compatible projector at an approximate viewing distance of 1 to 2 m. After viewing each sign, participants were asked to indicate its meaning. Young adults, healthy older adults and older adults with early stage dementia were tested in small groups (average of 5 people). Older adults with moderate to severe cognitive impairment were tested individually and gave the answer orally, their responses then recorded by a research assistant.

3. Results

3.1 Data Analysis Findings
Some of the most important demographic data are shown in summary form in Table 1. The moderately impaired group was older than the mildly impaired group ($p = .025$).

Average acuity was within normal limits for young adults, healthy older adults and mildly impaired older adults. Moderately impaired older adults had poorer visual acuity, which was significantly worse than that of healthy young adults (p = .025) and healthy older adults (p < .001). Scores on the SMMSE also showed a significant group effect (p < .001). Healthy young and older participants did not differ from each other (p = .975), but both of these groups differed significantly from the mildly impaired and moderately impaired groups (*p's* < .001). As well, the mildly impaired group scored significantly higher than the moderately impaired group (p < .001) on the SMMSE. As would be expected, there were also group differences on IADLs (p < .001), but this arose because the moderately impaired group had lower IADL scores than all other groups (p < .001), while all other groups were not discernibly different (*ps* > .07). Finally, there were no group differences on self-rated health (p > .11)

Table 2 provides the average comprehension scores for each age group for the signs broken down by category, whereas Table 4 displays comprehension performance separately for each sign for all age groups. There were several expected patterns in the data. First, the young healthy adults and older healthy adults were generally quite good at sign comprehension. However, way-finding signs produced difficulties even for the healthy older adults, whose comprehension scores were 23% lower than the younger group. Age deficits in comprehension were exacerbated in the presence of cognitive impairment: The moderately impaired group comprehended less than 25% of all signs.

These results were born out in several mixed-model analyses of variance (ANOVAs) that used a Geisser-Greenhouse correction for violations of sphericity (Maxwell & Delaney, 2004). The main effect of Sign Type was significant (p < .001, partial h^2 = .17), as was the effect of Group (p < .001, partial h^2 = .71). These effects are qualified by the Group X Sign Type interaction (p = .009, partial h^2 = .10). It appears as if the interaction arose because healthy older adults were generally quite good at sign comprehension but had difficulty with way-finding signs. Consistent with this interpretation, the Group X Sign Type interaction was eliminated when the healthy older group was removed from the analysis (p = .33, partial h^2 = .04). As well, a comparison of only the healthy younger and older adults revealed that only on the way-finding signs did the two groups differ in comprehension (p < .001).

It was hypothesized that the signs containing text, often with graphic supplements, would be more easily comprehended than signs with graphics alone and that this might be particularly true for the cognitively impaired elderly. Table 3 displays average comprehension for these two classes of signs for each of the groups tested. Clearly, signs containing text are more easily comprehended, and signs containing only graphics are problematic for older adults, in terms of absolute scores, especially for those with mild or moderate cognitive impairment. These trends were assessed with a Group X Sign Type (Text plus Graphic vs. Graphic Alone) ANOVA that yielded significant main effects of Group (p < .001, partial h^2 = .62), Sign Type (p < .001, partial h^2 = .36), and a Group X Sign Type interaction (p = .004, h^2 = .16).

Complimenting this analysis, we examined comprehension of two signs (fire extinguisher and no smoking) that existed in graphic only as well as text plus graphic formats. The average comprehension of the text plus graphic signs was 78% while that of the graphics only signs was 65%. This difference was significant ($p < .001$). The Sign Type X Group Effect was also significant ($p = .046$) and arose largely because only 23% of those in the moderately impaired group were able to comprehend the signs when there was no text in them.

There were several signs that were comprehended with very low frequency. They are a driving warning sign depicting a transition from a paved surface to a gravel road, a warning sign for radioactive materials, and way finding signs for a physician's office, recycling, a library, post office and auto repair garage (Figure 1). These are the most obvious candidates for re-design.

Is there a relation between psychometric estimates of cognitive function and sign comprehension? To answer this question, we determined the correlation between SMMSE scores and total comprehension scores, excluding younger adults. Within the three older groups, the correlation between the two measures was .81 ($p < .001$). Even when the analysis included only those older participants who had been identified as having either mild or moderate levels of cognitive impairment, the correlation between SMMSE score and sign comprehension scores was .72 ($p < .001$). Clearly, those who score poorly on briefly assessments cognitive function have difficulty comprehending many common signs.

Another approach to the functional importance of sign comprehension is through the relation between comprehension and activities important to independence. We determined the correlations between total comprehension scores and IADLs, excluding younger adults as before. The correlation was sizeable .75 ($p < .001$). When the analysis included only those older adults with some cognitive impairment, the correlation was still .68 ($p < .001$).

4. Conclusions

Throughout human history, efficient goal-oriented action has evolved in tandem with the ability to recognize and make use of environmental signals. In the natural world, these signals are often identical to the stimuli involved in effective action (e.g., a log over a rushing stream is directly perceived as an affordance for crossing). In modern societies, these signals are increasingly unnatural, and are constructed to convey information about abstract concepts that are not immediately perceptible (e.g., a library is in the vicinity). To respond appropriately, not only must the observer perceive the signal, but they must interpret its meaning, either through inference if it is novel or memory if it is not. This process of comprehension can be fast and straightforward as when a rightward arrow indicates the continuation of a hiking trail, but can also be fraught with ambiguity and error. The occasional comprehension failure may only result in a frustrating loss of efficiency. However, consistent failures to comprehend signage can place us at increased risk of harm to others or ourselves. That is, sign comprehension can be critical to functional independence in the domains of meal preparation, home safety, transport, medical care, etc. In the current study we investigated if and how sign comprehension differs between healthy young and old adults and between old adults with and without cognitive difficulties. In addition, we examined relations between sign comprehension and the ability to carry out instrumental daily living tasks related to banking, hygiene, mobility, etc.

In contrast to various other studies, we did not find substantial age differences between young and healthy older adults. These results may seem at odds with those of Dewar, et al (1996) and Hancock, et al (2004), both of which found age deficits in sign comprehension. The differences are more apparent than real and are likely due to variation in stimuli and samples. In fact, in our data, healthy older adults had poorer comprehension than the young on 44% of the driving signs. This compares well with Dewar, et al.'s data, in which older adults comprehended 39% of the driving signs less well than the young. Hancock, et al (2004) found that familiarity is an important factor in sign comprehension. Because many of the signs used in our study are familiar to healthy older adults, it is not surprising that they would be better able to comprehend their meaning. Importantly, however, we found that even healthy older adults have greater relative difficulty with way-finding signs (e.g., post office) that may be less important for safety, but influence the ease and convenience of performing everyday tasks.

If sign comprehension for some classes of signs is relatively well preserved in healthy older adults, it is profoundly error-prone in the presence of mild-to-moderate levels of age-related cognitive impairment. As in previous work (Brashear, et al., 1998; Carr, et al., 1998; Mitchell, et al, 1995), out data indicate a dramatic decrease in the comprehension of signage that is important in safe driving. However, there are two additional contributions of the present work. First, among those with dementia, comprehension is relatively worse for signs conveying warnings and those intended to assist with way-finding. Second, signs without text are problematic for those older adults with cognitive impairment.

There are a number of explanations for the comprehension deficits demonstrated by the cognitively impaired older person. Because cognitive impairment is associated with reduced activities of many types, it is possible that iconic signs are more poorly comprehended because they are seen less often and thus are less familiar. It is also possible that poor comprehension results because icons require a graphical-to-phonological-to-semantic mapping and retrieval that is difficult to execute for the cognitively impaired. Using signs that include both icons and text can facilitate comprehension via probability summation but also because the text comprehension can be completed with phonological-to-semantic mapping that is relatively well preserved.

If sign comprehension was only needed occasionally or for relatively unimportant activities, the difficulties experienced by the cognitively impaired older person would be interesting theoretically but of little practical import. However, this is not the case. As noted above, fast and accurate sign comprehension is required for safe and effective execution of many daily living activities like transportation, use of the health care system, shopping and the like. Thus, it should come as no surprise to find that those who are worse at sign comprehension are also experiencing greater difficulties in IADLs. In fact, one might make the argument that a more comprehensive measure of IADLs would include a sign comprehension component to quickly and objectively capture a person's ability to make proper use of some of the important signals present in their environs.

There are several recommendations prompted by these results. First, given that some signs are poorly comprehended by all people (see Figure 1 for some examples), designs should use these and similar data for target signage improvement. An excellent example of this kind of work comes from Kline and Fuchs (1993) image-processing approach to traffic sign development. Second, because signs that are easily comprehended by healthy young adults may be poorly comprehended by those who are older or less healthy, we must improve our sampling of participants to include a more heterogeneous user group when designing and evaluating signage. Finally, in those environments populated by the elderly and the cognitively impaired, it makes sense to avoid signage that relies only on graphic devices to convey its meaning. Visibility distance may be shorter for text-based signs (Kline, et al, 1990), but in relying only on iconic signage, comprehension is sacrificed for those who, arguably, need it most.

There are at least two directions for future research in this area. First, we have argued that improvements in sign comprehension for the cognitively impaired can be effected through the addition of text. We have provided some evidence for this in our analysis of those signs in the tested set that were available in both graphics only and text plus graphics format. It would be of benefit to determine if this increase in comprehension can be produced in a larger and representative set of signs.

Secondly, one can make the argument that the isolated format in which we presented the signs placed the cognitively impaired older people at a disadvantage because it deprived them of the environmental context on which they rely (Morrow, Ridolfo, Menard, Sanborn, Stine-Morrow, Herman, Teller, & Bryant, 2003). An extension of this research would then be to assess sign comprehension when signs are presented in their appropriate context. At the low-fidelity end, asking people to verbally report the meanings of signs that are shown in the environments in which they normally occur could do this. At the high-fidelity end, this could be accomplished in a virtual environment where comprehension could be operationalized as the execution of an appropriate action (e.g., stopping when presented with a STOP sign in a driving simulator).

6. References

Allen, R., Parseghain, Z, & Van Valkenburg, P. (1980). Simulator evaluation of age effects on symbol sign recognition. *Proceedings of the 24th Annual Meeting of the Human Factors Society.*

Al-Madani, H., & Al-Janahi, A.-R. (2002), Assessment of drivers' comprehensions of traffic signs based on their traffic, personal and social characteristics. *Transportation Research Record, Part F 5*, 63-76.

Brashear, A., Unverzagt, F, Kuhn, E., Glazier, B., Farlow, M., Perkins, A.,& Hui, S. (1998). Impaired traffic sign recognition in drivers with dementia. *American Journal of Alzheimer's Disease*, *13*, 131-137.

Canada Safety Council (2004). Web site. http://www.safety-council.org/training/55alive/55alive.htm

Carr, D., LaBarge, E., Dunnigan, K., & Storandt, M. (1998). Differentiating drivers with dementia of the Alzheimer type from healthy older persons with a traffic sign naming test. *Journals of Gerontology: Series A: Biological Sciences and Medical Sciences*, *53A*, M135-M139.

Craik, F.I.M. (1977). Human memory. In J. Birren & K.W. Schaie (Eds.), *Handbook of the psychology of aging*. New York: van Nostrand Reinhold.

Craik, F.I.M., & Simon, E. (1980). Age differences in memory: The roles of attention and depth of processing. In L.W. Poon, J.L. Fozard, L.S. Cermak, D. Arenberg, & L.W. Thompson (Eds.), *New directions for memory and aging* (pp. 95-112). Hillsdale, N.J.: Lawrence Erlbaum Associates.

Crowell, T.A., Luis, C.A., Vanderploeg, R.D., Schinka, J.A., & Mullan, M. (2002). Memory patterns and executive functioning in mild cognitive impairment and Alzheimer's disease. *Aging, Neuropsychology and Cognition, 9*, 288-297.

Day, R. (1988). Alternative representations. In G. Bower (Ed.), *Psychology of learning and motivation* (Vol. 22, p. 261-305). New York: Academic Press.

Dewar, R., Kline, D., & Swanson, A. (1996) Age differences in comprehension of traffic sign devices. *Transportation Research Record, 1456*, 1-10.

Driver's Handbook (on line). http://www.drivershandbook.com.

FHWA, U.S. Department of Transportation. (1988). *Manual on Uniform Traffic Control Devices for Streets and Highways.*

Halpern, D. F. (1984). Age differences in response time to verbal and symbolic traffic signs. *Experimental Aging Research*, *10*, 201-204.

Hancock, H., Rogers, W., Schroeder, D., & Fisk, A. (2004). Safety symbol comprehension: Effects of symbol type, familiarity and age. *Human Factors, 46*, 183-195.

Higgins, K.E.; Wood, J., & Tait, A. (1998). Vision and driving: Selective effect of optical blur on different driving tasks. *Human Factors*, *40*, 224-232.

Hulbert, S., Beers, J, & Fowler, P. (1979). *Motorists' Understanding of Traffic Control Devices*. AAA Foundation for Traffic Safety, Falls Church, VA.

Kline, D.W., & Fuchs, P. (1993). The visibility of symbolic highway signs can be increased among drivers of all ages. *Human Factors*, 35, 25-34

Kline, T.J.B., Ghali, L.M., Kline, D.W., & Brown, S. (1990). Visibility distance of highway signs among young, middle-aged, and older observers: icons are better than text. *Human Factors*, 32, 606-619

Kline, D., & Scialfa, C. (1997). Sensory and perceptual functioning: Basic research and human factors applications. In A.D. Fisk & W.A. Rogers (Eds.), *Handbook of Human Factors and the Older Adult.* San Diego: Academic, pp. 27-54.

Lawton, M.P., & Brody, E.M. (1969). Assessment of older people: Self-monitoring and instrumental activities of daily living. *Gerontologist, 9*, 179-186.

Maxwell, S.E., & Delaney, H.D. (2004). *Designing experiments and analyzing data: A model comparisons perspective, 2nd ed*., Mahwah, N.J.: LEA.

Mitchell, R., Castleden, C., & Fanthome, Y. (1995). Driving, Alzheimer's disease and ageing: A potential cognitive screening device for all elderly drivers. *International Journal of Geriatric Psychiatry*, *10*, 865-869.

Moeur, R. C. (1998). *Manual of Traffic Signs*. [On-line]. Available: http://richardmoeur.com.

Molloy, W. (1999). The Standardized Mini Mental Status Exam. Troy, Ontario: New Grange Press.

Morrell, R., Park, D., & Poon, L. (1990) effects of labeling techniques on memory and comprehension of prescription information in young and old adults. *Journal of Gerontology: Psychological Sciences, 45*, 166.-172.

Morrow, D., Ridolfo, H., Menard, W., Sanborn, A., Stine-Morrow, Elizabeth, Magnor, C., Herman, L., Teller, T., & Bryant, D. (2003). Environmental support promotes expertise-based mitigation of age differences on pilot communication tasks. *Psychology and Aging, 18*, 268-284.

Sivak, Michael; Olson, Paul L. (1982). Nighttime legibility of traffic signs: Conditions eliminating the effects of driver age and disability glare. *Accident Analysis & Prevention 14*, 87-93.

Stutts, J.C., Stewart, R. & Martell, C. (1998). Cognitive test performance and crash risk in an older driver population. *Accident Analysis and Prevention, 30*, 337-346.

U.S. Department of Transportation (1998). *Older Driver Highway Design Handbook.*

U.S. Department of Transportation (2000). *Improving Driver Recognition of In-Vehicle Icons*. U.S. Dept. of Transportation. Federal Highway Administration. Report No. FHWA-RD-00-091.

U.S. Department of Transportation (2001). *Guidelines and recommendations to accommodate older drivers and pedestrians*. U.S. Department of Transportation-Federal Highway Administration Technical Report No. FHWA-RD-01-051

Willis, S. (2004). Technology and learning in current and future older cohorts. In R. Pew and S. Van Hemel (Editors), *Steering Committee for the Workshop on Technology for Adaptive Aging*, National Research Council. Washington, D.C.

Wolf, J., & Wolgalter, M. (1993). Test and development of pharmaceutical pictorials. *Interface, 93*, 187-192.

7. Appendix - Tables 1 – 3, Figure 1

Table 1. Participant information concerning mean age (S.D.), self-rated health, mental status, independence in tasks of daily living, and corrected Snellen acuity. Standard deviations are presented in parentheses.

Group	Mean Age	Self-rated health (1-5)	SMMSE (0-30)	IADL (1-16)	Snellen (left) 20/	Snellen (right) 20/
Young adults	22.50 (5.91)	3.8 (0.83)	30 (0)	16 (0)	30.90 (13.18)	28.75 (11.91)
Healthy older adults	77.24 (5.61)	3.86 (.96)	29.48 (1.03)	14.71 (2.08)	20.24 (5.80)	21.90 (5.80)
Older adults with early stage dementia	74.81 (7.22)	3.81 (.98)	23.57 (5.41)	14.44 (1.89)	35.71 (39.03)	34.15 (22.71)
Moderately to severely impaired older adults	80.89 (7.87)	3.21 (.98)	10.95 (5.44)	5.00 (2.69)	54.21 (26.10)	57.11 (55.03)

Table 2. Sign Comprehension by Sign Type and Group. Descriptive Statistics

	GROUP	Mean	SD
Regulatory Driving	Young Adults	0.93	0.09
	Healthy Older Adults	0.90	0.10
	Early Stage Older Adults	0.66	0.22
	Moderately to Severely Impaired Older Adults	0.33	0.21
	Total	**0.71**	**0.29**
Warning Driving	Young Adults	0.93	0.09
	Healthy Older Adults	0.89	0.15
	Early Stage Older Adults	0.70	0.24
	Moderately to Severely Impaired Older Adults	0.23	0.19
	Total	**0.70**	**0.32**
Warning	Young Adults	0.89	0.11
	Healthy Older Adults	0.82	0.15
	Early Stage Older Adults	0.61	0.44
	Moderately to Severely Impaired Older Adults	0.31	0.21
	Total	**0.66**	**0.34**
Way-Finding	Young Adults	0.86	0.13
	Healthy Older Adults	0.62	0.13
	Early Stage Older Adults	0.58	0.23
	Moderately to Severely Impaired Older Adults	0.21	0.15
	Total	**0.57**	**0.28**

Table 3. Comprehension of Graphic Signs vs. Graphic and Text Signs by Group: Descriptive Statistics

		Mean	SD
Signs with Text & Graphics	Young Adults	0.97	0.05
	Healthy Older Adults	0.93	0.10
	Early Stage Older Adults	0.69	0.42
	Moderately to Severely Impaired Older Adults	0.54	0.26
	Total	**0.79**	**0.30**
Graphics-Only Signs	Young Adults	0.88	0.10
	Healthy Older Adults	0.73	0.12
	Early Stage Older Adults	0.61	0.22
	Moderately to Severely Impaired Older Adults	0.20	0.15
	Total	**0.61**	**0.29**

Table 4. Accuracy by Sign by Group

Sign Name	Young	Healthy Older Adults	Early-Stage Older Adults	Moderately to Severely Impaired Older Adults	Average
Bike Lane	0.95	0.95	0.85	0.63	0.81
Merging Roads	0.75	0.90	0.35	0.26	0.51
Road Construction	0.9	0.86	0.65	0.21	0.57
By-road Merges	0.8	0.90	0.45	0.11	0.49
Detour	0.95	0.95	0.55	0.47	0.66
Stop	1.0	1.0	0.95	0.79	0.91
Yield	1.0	0.95	0.8	0.58	0.78
No Turns	1.0	1.0	0.75	0.11	0.62
No bikes	0.95	0.95	0.85	0.21	0.67
Do Not Enter	0.95	1.0	0.6	0.89	0.83
Pedestrians Keep Left	0.95	1.0	0.65	0.32	0.66
Left Turn Only	0.8	0.76	0.45	0.16	0.46
Keep Right	0.95	0.81	0.55	0.53	0.63
No Parking	1.0	1.0	0.9	0.21	0.70
Reserved for Disabled	0.95	0.95	0.8	0.11	0.62
No Pedestrian Thoroughfare	1.0	1.0	0.75	0.11	0.62
No Trucks	0.9	0.86	0.85	0.21	0.64
Change to Gravel Road	0.95	0.29	0.4	0.05	0.25
Restricted Lane Ahead	1.0	0.95	0.45	0.63	0.68
Deer Crossing	1.0	0.95	0.75	0.32	0.67
Pedestrian Crossing	0.85	0.95	0.75	0.26	0.66
School-children Crossing	0.9	0.95	0.75	0.37	0.69
Traffic lights ahead	1.0	0.81	0.65	0.21	0.56

Table 4, Continued

Sign Name	Young	Healthy Older Adults	Early-Stage Older Adults	Moderately to Severely Impaired Older Adults	Average
Slippery Road	0.85	0.67	0.85	0.11	0.54
Playground	0.8	0.95	0.85	0.05	0.62
Stop Sign Ahead	1.0	0.86	0.8	0.05	0.57
Yield Sign Ahead	1.0	0.90	0.5	0.11	0.50
Fire Danger	0.85	0.86	0.3	0.05	0.40
No Smoking (text plus graphics)	1.0	0.95	0.8	0.53	0.76
No Smoking (graphics only)	1.0	0.81	0.65	0.32	0.59
Hard Hat Area	1.0	1.0	1.0	0.53	0.84
Slippery When Wet	1.0	1.0	1.0	0.53	0.84
Fire Extinguisher (text plus graphics)	1.0	0.76	0.7	0.53	0.66
Fire extinguisher (graphics only)	1.0	0.57	0.65	0.16	0.46
Radioactive Area	0.45	0.43	0.2	0.05	0.23
Poison	0.95	0.95	0.35	0	0.43
Dog Walking Area	0.65	0.90	0.6	0.37	0.62
Nursing room	0.9	0.81	0.4	0.05	0.42
Stairwell	0.85	0.95	0.6	0.21	0.59
Hotel	1.0	0.81	0.85	0.26	0.64
Doctor’s Office	0.5	0.71	0.4	0.05	0.39
Airport	1.0	0.90	0.7	0.37	0.66

Table 4, Continued

Sign Name	Young	Healthy Older Adults	Early-Stage Older Adults	Moderately to Severely Impaired Older Adults	Average
Bus Station	0.9	0.90	0.7	0.21	0.61
Train Station	0.95	0.43	0.8	0.53	0.58
Shopping Area	0.65	0.57	0.45	0.21	0.4
Eating Area	0.75	0.57	0.65	0.21	0.48
Garage	0.5	0.52	0.25	0	0.26
Gas Station	1.0	0.71	0.8	0.32	0.61
Recycling	0.9	0.19	0.3	0	0.16
Restaurant	0.95	0.62	0.35	0.05	0.34
Information Office	0.9	0.67	0.55	0.16	0.46
Library	0.75	0.38	0.4	0	0.26
Harbor	0.65	0.86	0.6	0.16	0.54
Telephone	0.95	0.76	0.8	0.21	0.59
Snow	0.85	0.76	0.35	0.05	0.39
Accommoda-Tion	1.0	0.38	0.55	0.21	0.38
Elevator	0.65	0.57	0.45	0.05	0.36
Shower	0.9	0.71	0.3	0	0.34
First Aid	0.95	0.29	0.65	0.37	0.43
Fishing Area	0.95	0.38	0.85	0.37	0.53
Garbage Disposal	0.95	0.24	0.9	0.37	0.50
Men’s Washroom	1.0	0.90	0.8	0.53	0.74
Women’s Washroom	1.0	1.0	0.8	0.74	0.85
Post Office	0.95	0.43	0.55	0.05	0.34
Drinking Water	0.7	0.43	0.4	0.16	0.33

Figure 1. Signs with worst comprehension. In order; transition to gravel road, radioactive area, physician's office, recycling, library, post office