CRASH AVOIDANCE IN VIRTUAL SPACE:
Age Differences in Emergency Evasive Maneuvers

Kristi L. Arakaki
Biology and Accounting Honors Thesis Student
Geriatric Medicine Program
John A. Burns School of Medicine

ABSTRACT

One of the greatest challenges for astronauts involves operating and maneuvering the space shuttle, the single-most sophisticated and complex transportation vehicle ever created. The ability of astronauts to perform complex neuromotor tasks such as collision avoidance responding during docking and landing procedures is critical not only to their survival but also to preventing multi-million dollar damage to the shuttle. The primary objective of this research was to develop a simulated collision avoidance testing (SCAT) system and procedure and to conduct a pilot study to examine its sensitivity to age of the vehicle operator. A second purpose was to develop a battery of tests and to examine the relationship between attention skills and collision avoidance ability. The degree of skill exhibited by an individual in avoiding automobile collisions in the simulator is expected to be a useful indicator of his/her ability to perform other related complex vehicle-maneuvering tasks such as those required for shuttle operation.

Eighty-seven participants, with approximately equal numbers of males and females in each of four age groups have been tested to date. The four age groups included 6-12 year old children, 20-39 year old young adults, 60-74 year old older adults and 75+ year old elderly adults. Five tasks were performed: (1) Simulated Collision Avoidance Testing **(SCAT)** system, (2)**Visual Elevator** Task, (3)**Trails B** Test, (4)**Telephone Directory Search** Task, and (5)**Telephone Number Dialing** Task. The total test time was approximately 90-120 minutes. Results showed parallel deficiencies in collision avoidance responding and cognitive task performance of children, older adults, and elderly adults compared with young adults. Significant collision avoidance skill declines occured in elderly adults over the age of 75. These declines were nearly three times greater in elderly females than in elderly males. Older adults and elderly adults were also slower than young adults especially on trials that contained degraded visual stimuli (in the form of fog and low contrast). Across attention tasks, children, older adults, and elderly adults performed worse than young adults in both the presence and absence of auditory distraction. This research helps identify when collision avoidance abilities and cognitive function reach maximal development, when they begin to decline, and the possibility of compensatory measures for recognized deficiencies. Implications of this research to space research include: observing the effects of age and sex on moving-vehicle collsion avoidance responding and cognitive function for aircraft operators, providing a means of testing and predicting collsion avoidance reactive capacity of astronaut and pilot candidates, anticipating potential problems of aircraft operators of advanced age, and extending the number of years of safe flying by astronauts.

INTRODUCTION

The ability to avoid moving-vehicle collisions is a complex procedure which draws upon the coordinated action of an individual's cognitive and motor skills. In the past, collision avoidance responding ability could not be examined easily as such an examination procedure would have entailed placing people in automobiles, subjecting them to perilous driving conditions, and exposing them to high risks for driving collisions. Such a procedure would jeopardize the safety of human test participants and would be extremely costly in terms of equipment damage. Virtually the only source of collision avoidance data lay within accident reports. However, the advent of computer-based driving simulators ushered in a new era for collision avoidance research. Such simulators endowed researchers with a means of safely manipulating driving conditions to determine the degree to which variables proven to influence driving ability such as visibility conditions (Graham, 1995) or maneuver difficulty, affect the collision avoidance ability of individuals across age and sex groups. Information obtained from this type of study holds tremendous implications for organizations such as the National Aeronautic and Space Administration or airline companies which rely heavily upon human-operated moving vehicles. Understanding the degree of collision avoidance skill declines that occur at a certain point in the human life-span will enable the institutions to take appropriate precautions and provide specific assistive devices to compensate for potential skill declines experienced by their aircraft pilots. Assistive devices such as impending collision warning systems would be of potential value as these devices have been shown to significantly improve braking response times and reduce the frequency of collisions among participants in driving simulation experiments (Suetomi, 1995). Because the driving simulator represents a relatively new technological advance, its use has been limited and much remains to be discovered about the factors influencing moving-vehicle collision avoidance skill. Therefore, the primary purpose of this research was to develop a simulated collision avoidance testing (SCAT) apparatus and procedure and to conduct a pilot study to examine the SCAT system sensitivity to age of the vehicle operator. A second purpose was to develop a battery of everyday attention tests and to examine the relationship between attention skills and collision avoidance ability that has been demonstrated in previous research (e.g. Wiseman, 1996).

METHOD

Participants.

Elghty-seven participants with approximately equal numbers of males and females in each of four age groups have been tested to date. The four age groups included 6-12 year old children (9 males, 13 females), 20-39 year old young adults (16 males, 15 females), 60-74 year old older adults (11 males, 8 females), and 75+ year old elderly adults (8 males, 7 females). The majority of the children were recruited from Punahou School by the research principal investigator. The majority of the young adults were students attending the University of Hawai'i. The majority of the older adults were volunteers of previous research projects connected with the University of Hawai'i Geriatric Medicine Program. The participants were healthy with no apparent neuropathology and no medication was thought to affect their performance on the tests.

Apparatus.

The experimental task was performed on a commercially available personal computer product. STISIM is a low cost, fully interactive driving simulator designed to represent a range of psychomotor, divided attention, and cognitive tasks involved in driving. (System Technology, Inc., 1999) STISIM comes in a 2D system which operates on a 486 or higher IBM compatible DOS computer with Texas Instrument Graphic Adapter (TIGA) video card or a new 3D system which runs off a Pentium 166 or higher IBM compatible computer with WindowsNT and a 3Dfx video card.

STISIM (Version 8) offers several features for examining driver abilities that includes vehicle dynamics, visual and auditory displays, and a performance measurement system. Driving tasks and events were easily programmable with a unique Scenario Definition Language that allowed the user to specify an arbitrary sequence of tasks, events, and performance measurement intervals. This allowed the examinee/trainee to perform various maneuvers that were common crash scenarios (such as front-to-rear end collisions). A utility program called SimMastr provided a higher level interface for STISIM. This allowed the experimenter to specify participants information, control certain aspects of the simulation run, launch a wide variety of simulation scenarios, and get a quick summary of each run.

The microcomputer used to test for SCAT was a 2D systems that operated on an Intel Pentium 200 MMX platform running Microsoft DOS 6.22. The 2D system also included a TIGA video card, a SoundBlaster AWE 64 sound card with an analog joystick, 64 Mb EDO RAM, two display screens (driver and experimenter), a ThrustMaster Formula T2 steering wheel with brake and accelerator pedal, and a STISIM proprietary Dongle key.

Tasks.

Collision avoidance responding was tested on the driving simulator. In addition, four tasks focusing on attention were performed (1) Visual Elevator (attention switching test), (2) Trails B (attention switching test), (3) Telephone Directory Search (visual search test), and (4) Telephone Dialing task (short-term memorization test).

The participants tested on **Simulated Collision Avoidance Test (SCAT)** on STISIM were asked to perform a series of crash avoidance maneuvers in a virtual driving environment. Participants were instructed to drive through each run as quickly as possible with as few errors as possible. Their task was to drive down the middle lane of a three lane freeway at 55 mph. At specific intervals during the run, a rear view of five vehicles appeared on the freeway, two in the outer lanes and one in the middle. As the partcipants approached the five vehicles, the brake lights of the five vehicles are activated. When this ocurred, the participants were required to respond with the correct crash avoidance maneuver (swerve to the left lane, swerve to the right lane, stop, or continue through). Once they completed their menuver, they returned to the center lane and maintained the speed of 55 mph to get ready for the next formation of vehicles and maneuver. For the pre-cued SCAT trials, participant received two runs with two visibility conditions (clear and light fog with low contrast). For the choice SCAT trials, participants received two runs with the same two visibility conditions. The SCAT maneuvers: left swerve, right swerve, and stop, were the same for pre-cued and choice runs. The independent variables in this exercise were age, sex, type of run (pre-cued or choice), visibility condition, and driving maneuver (left swerve, right swerve, or stop). The dependent measures were perception reaction time, movement time, response time, number of crashes, and time to trial completion.

For the **Visual Elevator task** participants viewed three different symbols, an elevator door, a large vertical arrow pointing up, and a large vertical arrow pointing down. These symbols were presented in varying order and varying number in a series. Each elevator door represented a floor. Each vertical arrow acted as a signal indicating upward movement of the elevator and each vertical down arrow acted as a signal indicating downward movement of the elevator. Thus, the floor (represented by elevator doors) which appeared immediately after the up arrow, was one level higher than the floor immediately before the up arrow. Similarly, the floor appearing immediately after the down arrow was one level lower than the floor immediately before the down arrow. The participant's goal was to correctly identify the floor number of the last floor symbol in a series as quickly as possible. Participants' scores were based on whether the floor number of the last floor was correctly identified and the amount of time in seconds required to arrive at the last floor in each of the ten trials. The independent variables in this exercise were age, sex, and the number of "switches." The number of "switches" which was equivalent to the number of times the participant reversed his/her counting order, had a direct relationship to the level of difficulty of that trial. The dependent measures included time to complete each trial and the number of errors committed by the participant. The participant was deemed to have committed an error if he/she incorrectly identifies the floor number of the last floor symbol in a trial.

For the **Trials B Task**, participants were presented with a sheet printed with the letters A through L and the numbers 1 through 13. The letters and numbers were printed randomly across the page. The participant connected the cirlces in order, alternating numbers and letters in consecutive, ascending order (1 to A, A to 2, 2 to B, and so on) until they reached the 'End.' The time required to complete this task was recorded. The independent variables in this exercise included age and sex. The dependent measures included the time required to complete the exercise by connecting all the circles in order.

For the **Telephone Directory Search**, participants were presented with a simulated telephone directory page with a pair of symbols printed next to each phone number. There were four types of symbols: a square, circle, star, or "X." In the first trial, the participant searched the entire directory, circling each pair of identical symbols (i.e., two squares, two circles, two stars, or two "X" symbols). The goal was to circle as many pairs as possible in the least amount of time. The second trial was identical to the first trial, with the exception that auditory loading (i.e., counting the number of tones) was introduced. Participants counted the number of tones presented in several consecutive series while simultaneously circling as many pairs of identical symbols as quickly as possible. The independent variables in this exercise included age, sex, and the presence of an auditory loading factor. The dependent measures included the number of targets found and the time taken to find the targets.

For the **Telephone Dialing Task**, participants were presented with a simulated telephone directory page. A small, self-sticking arrow was pasted such that it pointed to a phone number. The directory page was presented to the participant for two seconds. During this timeinterval, the participant memorized this number. At the end of the interval, the participant immediately dialed the number on a touch-tone phone pad and then verbally stated the phone number he/she intended to dial. The participant repeated this procedure for a total of five trials with the same two-second viewing interval and then for five trials with a five-second viewing interval (using a different phone number during each trial). In the second half of the exercise, a loading factor was introduced. Participants repeated the aforementioned procedures while repeating the sentence, "My name is (participant's name)" when viewing the number and dialing the number. The independent variables in this exercise included age, sex, the allowed viewing time, and the presence of a verbal loading factor. The dependent measures included the ability to correctly memorize and dial the phone number.

Treatment of Data

Descriptive and inferential statistics were conducted on each dependent measure using the Statistical Analysis System software according to general linear models mixed analysis of variance design, with post-hoc tests done manually, at the $p<0.5$ level of significance.

PRELIMINARY RESULTS AND DISCUSSION

In the first semester of my fellowship I was able to design the tests, collect and do preliminary analysis of the data, and report initial findings. During the summer I plan to conclude analyses, including the intercorrelation of the attention tasks with SCAT measures, and finish writing my honors thesis.

Preliminary results of this study showed parallel deficiencies in collision avoidance responding and cognitive task performance of young children, older adults, and elderly adults compared with young adults. In SCAT tasks, older adults over the age of 60 were slower than young adults as individuals past this point in the life span experience decline in complex skills critical to driving safety such as time perception and time-to-approach estimation (Siu, 1996). Significant declines in collision avoidance responding skills occured in adults over the age of 75 and these declines were three times greater for females than males. Approximately 86 percent of females between the ages of 75 and 90 experienced crashes on all 10 collision avoidance response tests while 29 percent of the males in this age bracket crashed on all 10 tests (Figure 1). Females not only showed greater declines in collision avoidance response skills in late adulthood (75+ years), but females also exhibited slower development of collision avoidance response skills during childhood (6-12 years). Approximately 17 percent of females between the ages of 6 and 12 experienced crashes on all 10 collision avoidance response tests while none of the males in this age group crashed on all 10 tests. Across attention tasks, children and elderly adults performed worse than young adults especially in the presence and absence of auditory distraction (Figures 2-4). For the Trails B task, the age, sex, and age by sex interaction was significant: males were faster than females after 13 years of age, with females faster than males in the 6-12 age group. However, the female advantage in the children may be caused by the average age of the girls being two years older than that of the boys.

CONCLUSIONS

This research has succeeded in developing a simulated collision avoidance testing system that is sensitive to the age and sex of the vehicle operator. This research also developed a test battery composed of attention tasks, which was sensitive to the age of test participants. Implications of this research to space exploration efforts include the development of tests which may predict the collision avoidance capacity of astronaut and pilot candidates. The understanding gained through this research may also aid in timely anticipation of potential problems facing elderly aircraft operators, thereby allowing for the implementation of intelligent assistive devices. The underlying benefit is to promote and extend the years of safe flying for astronauts and other aircraft operators, as well as drivers in ground vehicles.

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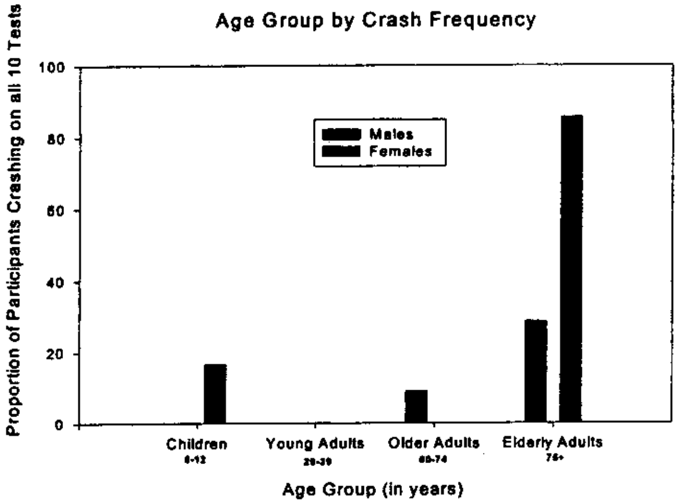

Figure 1. Proportion of participants per age group crashing on all 10 tests. These crashes are presumed fatal. Nearly all elderly females failed to avoid crashes on all collision avoidance tests.

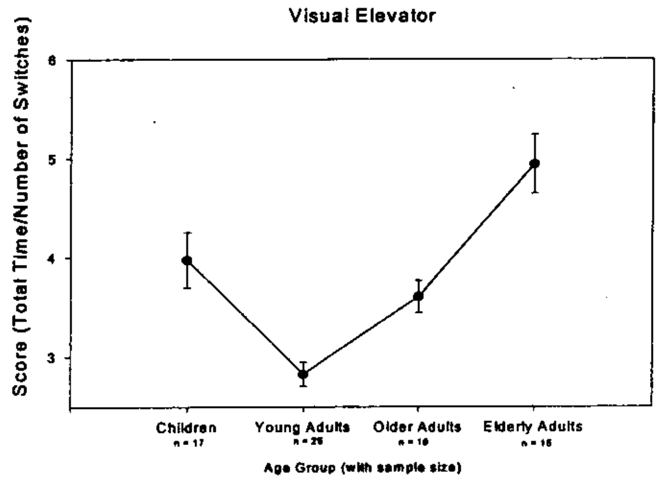

Figure 2. Mean score and standard error by age group for the Visual Elevator Attention Task. Young adults exhibit the best performance as seen in the low ratio of task completion time to task complexity (number of switches).

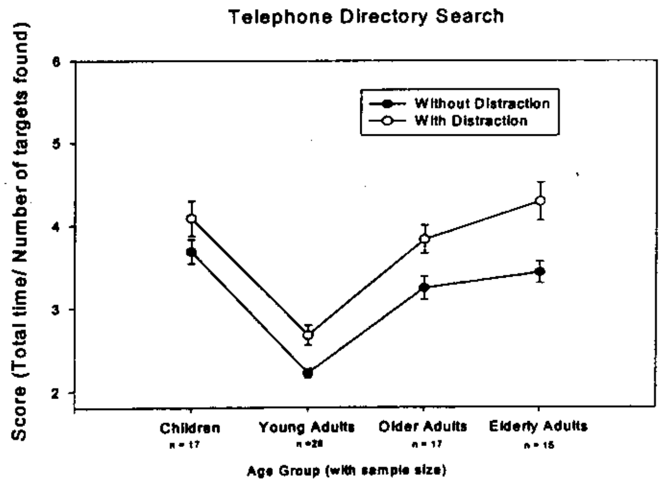

Figure 3. Mean score and standard error by age group with and without distraction for the Telephone Directory Search Task. Young adults exhibit the best performance as seen in the low ratio of task completion time to number of targets found.

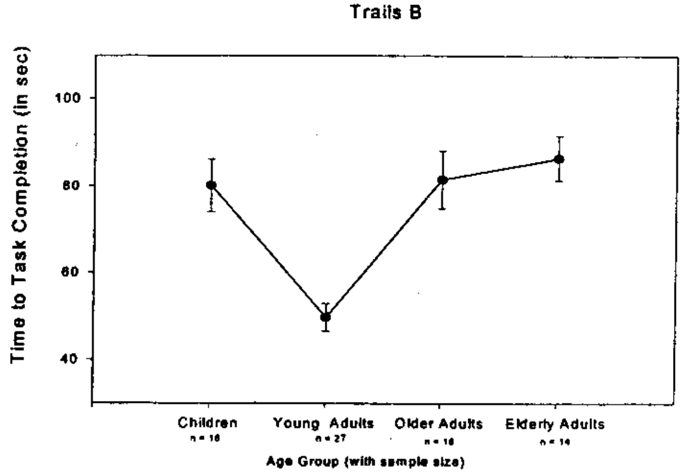

Figure 4. Mean score and standard error by age group for the Trails B Attention Task. Young adults exhibit the best performance reflected in the short task completion time.