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Effects of Gender and Athletic Participation on Driving Capability

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This study sought to determine if spatiotemporal skills, represented by success in high level sport, transfer to driving and, if so, whether such transfer is mediated by the gender of the driver. Using an emergency-braking test, we compared the driving ability of male and female athletes and non-athletes and showed that athletes achieved significantly longer and therefore superior durations for time-to-contact. The advantage of athletic participation thus did not appear in movement time but rather in the ability to produce desirable performance in context. We found that males and females did not differ significantly with respect to driving, however, involvement in sport apparently transfers to aspects of driving and so provides benefits beyond the intrinsic reward of the sports activities themselves.

braking response   gender differences   athletic involvement

1. INTRODUCTION

It is clear that within the accident record there are large and consistent gender differences in various forms of collision involvement (Evans, 1991). However, the differential pattern is not a simple one that involves a single, or even

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a limited set of accident configurations. In terms of inherent capabilities, there are established gender differences in certain cognitive and psychomotor abilities (see Maccoby & Jacklin, 1974; Thomas & French, 1985; Watson & Kimura, 1991), although whether there is a direct link between such differences and subsequent accident involvement and what the nature of this possible link might be, have yet to be determined. From previous research, we have shown that there are *average* gender differences in the perception of time (Block, Hancock, & Zakay, 2000), a disparity that is also evident in the capacity to estimate time-to-contact (Hancock & Manser, 1997; Manser & Hancock, 1996), which is one facet of performance often implicitly linked to collision events. However, embedded in this average disparity are large *individual* differences and consequently it is difficult to establish consistent assertions about any one single individual driver, male or female. One crucial question, and the focus of our work here, is whether and how there are gender differences in particular driving-related capabilities and if such differences exist, whether they are mediated by perceptual-motor skill level derived from participation in other spatiotemporal demanding activities. A highly practical facet of this present investigation therefore concerns whether participation in upper-level sport competition might facilitate driving response in highly demanding circumstances.

Studies on gender-related differences in driver accident involvement reveal that females and males differ with respect to certain decision-making strategies. Through the use of self-regulation, females appear less likely to expose themselves to high-demand, high-stress driving circumstances. Consequently, if and when they are eventually faced with situations such as emergency braking response, females may prove at greater risk because of this prior avoidance strategy. The direct concern here is if and how high-level sport experience holds the potential to modify such behavior. In non-driving contexts, research indicates that female athletes respond significantly faster to game and non-game stimuli (Allard & Starks, 1980) and demonstrate increased accuracy in recalling visual display structures (Borgeaud & Abernethy, 1987) when compared to non-athletic females. If such skills are directly transferable, then participation in athletics may enhance females' ability to avoid vehicular accidents. In respect of these questions, the present study was designed to determine if skills developed in competitive athletics, a highly demanding, spatiotemporal activity, transfer to driving competency (i.e., a function of learned capability), and whether such transfer is mediated by participant gender (i.e., an intrinsic attribute). We evaluated the association between perceptual-motor competence and driving performance through the use of high-fidelity driving simulation. Our specific hypotheses were that (a) the high-competence group (athletes) would outperform the low-competence group (non-athletes), (b) within each competency group, there would be no gender difference, and (c) the high-competence female athletes would outperform the low-competence male non-athletes. Such a pattern of findings would confirm the primacy of competency in affecting driving performance over intrinsic differences due to gender. Finally, we sought to determine which aspect of competency was responsible for superior performance, whether perceptual and strategic skills or direct psychomotor skills.

2. EXPERIMENTAL METHOD

2.1. Experimental Apparatus

Interactive driving scenarios were software programmed and displayed in the University of Minnesota's Human Factors Research Laboratory's single-screen driving simulator. The front-projection simulator is a high-fidelity driving system that allows for 60° of forward viewing area to immerse the participant in a virtual driving environment. Driving scenes are programmed with SGI Performer Graphics Libraries, displayed with an SGI Indigo2 and projected through an Electrahome ECP-3100® projector. Display resolution was 1024×768. A full-sized 1990 Accord served as the simulation vehicle. The vehicle was equipped with sensors for gas, brake, and steering control, facilitating real-time driver input. A torque motor attached to the steering wheel provided steering force feedback to the driver.[1]

2.2. Experimental Participants

Twenty-four individuals (12 male, 12 female) volunteered to participate in this study. The participants' ages ranged between 18 and 24 years ($M = 20.4$ years, $SD = 1.93$) and they reported to have between 2 and 9 years ($M = 4.7$ years) of driving experience. All participants were licensed drivers and had normal or corrected-to-normal vision. The average age of the male partici-

[1] Graphic representation of these facilities can be seen on the website at www.hfrl.umn.edu.

pants was 21.0 (*SD* = 2.13) and for the female participants it was 19.8 (*SD* = 1.67) years. Males had an average of 5.0 years driving experience and females had an average of 4.4 years of driving experience. They were each given US $10 for participating in the hour-long experimental session. Of the total participants, 13 were classified as athletes (6 males, 7 females) and 11 were classified as non-athletes (6 males, 5 females). Participants were classified as an athlete if they were currently participating in a Division I University athletic team. An overt attempt was made to recruit athletes who were participating in sports with strong closed-loop elements (i.e., sports such as baseball and tennis that require the participant to use feedback from the environment to moderate behavior in order to achieve a goal), versus open-loop elements (i.e., sports that require the participant to execute a standardized action, without continuous use of on-going feedback; see Poulton, 1957; Schmidt, 1988). The final convenience sample included swimmers (n = 6), golfers (n = 2), track athletes (n = 2), crew (n = 2), and baseball and football (n = 1), with one athlete's sport remaining unspecified. Participants were classified as non-athletes if they had never participated in Division I athletics and were not currently participating in an organized sports team. In actuality, only 1 non-athletic participant had limited exposure to an organized sports team (intramural soccer). Some non-athletic participants reported various degrees of previous activity in high school sports.

2.3. Experimental Procedure

All participants signed an informed consent form after having read a description of the experimental procedures and asking any clarifying questions. Participants then received practice-to-criteria training on the simulator controls. All participants had to demonstrate control of vehicle speed, steering, and lane control in the practice driving scenario. Subsequent to completion of satisfactory training, individuals participated in the experimental trials. The experimental scenario was a modified version of a braking scenario described by Van Winsum and Brouwer (1997) and Van Winsum and Heino (1996). Drivers controlled their vehicle on a two-lane road with 11.8-foot (3.6 meter) lanes and a 9.8-foot (3-meter) shoulder. The roadway was painted with a broken center line and a solid shoulder line. The peripheral environment contained some structures and non-task-related signage, producing a rural-like driving environment, see Figure 1. Participants were instructed to accelerate their vehicle to a "safe and comfortable" speed and to maintain their lane position. Approximately 0.62 miles (1000 meters) into the drive, a second vehicle (i.e., the lead vehicle), merged into the lane from a parked position on the shoulder. The second vehicle accelerated at 8.95 mph (4 m/s^2) to achieve a target speed of either 50 mph (22.35 m/s or 80.47 km/h) or 40 mph (17.88 m/s or 64.37km/h) depending upon the experimental order. Participants were instructed to approach the vehicle and maintain a safe and comfortable following distance and not to pass this vehicle. At this juncture the experimental procedure differed.

In the preferred time headway (PTH) trial, participants drove behind the lead vehicle and achieved a safe and comfortable distance, see Figure 1. Participants were instructed to maintain the constant distance for approximately 5 min, after which the PTH trial ended. In the Braking Trials drivers were instructed first to maintain the safe and comfortable distance. Prompted by the experimenter, the participants were requested to drive at a closer distance and maintain a new following distance. This continued until a time headway of 1.0 s was reached. At that moment the lead vehicle's brake lights lit, and the vehicle decelerated at –6.71 mph (–3 m/s) to half its original speed, either 25 mph (11.18 m/s) or 20 mph (8.94 m/s). The critical 1.0 s time headway threshold was selected on the basis of pilot testing with threshold values ranging between 0.6 to 1.2 s. This headway produced both open- and closed-loop movements (a ballistic limb movement from the gas to the brake, then moderated braking based on information available in the scene). Control trials replicated the Braking Trials except the lead car did not brake, regardless of the achieved time headway (Control-Nothing), or the lead car sped up at 1.0 time headway (Control-Acceleration).

Figure 1. Participants' view of the lead vehicle.

TABLE 1. Summary of Trials With Order Type and Lead Vehicle (LV) Speed

Order One			Order Two		
Trial	Type	LV Speed	Trial	Type	LV Speed
1	PTH	50 mph	1	PTH	50 mph
2	control-acceleration	50 mph	2	control-acceleration	40 mph
3	control-nothing	50 mph	3	control-nothing	40 mph
4	braking	50 mph	4	braking	40 mph
5	control-nothing	40 mph	5	control-nothing	50 mph
6	control-acceleration	40 mph	6	control-acceleration	50 mph
7	control-nothing	40 mph	7	control-nothing	50 mph
8	braking	40 mph	8	braking	50 mph

Notes. PTH—preferred time headway, 40 mph = 64.37 km/h, 50 mph = 80.47 km/h.

Each participant drove eight experimental trials and a summary of trial order is provided in Table 1. All participants drove the PTH trial first. Orders one and two were represented essentially equally across gender and athletic status. Inter-trial intervals were approximately 1 min. Participant vehicle speed, lead vehicle speed, accelerator actuation (0–100%), brake actuation (0–100%), and distance headway (bumper-to-bumper distance between lead and following vehicle) data were collected every second (1 Hz) during non-braking segments and 5 times per second (5 Hz) during braking segments. Following the experiment, each participant completed a questionnaire consisting of demographic information, driving experience, and sport participation. Further, questions were asked about the control "feel" of the simulation and each participant's experience during the braking trials. Subsequent to completing the questionnaire, all participants were debriefed and were told in general terms the background, purpose of the investigation.

2.4. Experimental Measures

From the raw data collected, the following measures of behavior were identified: (a) the time at the moment the lead car braked (T_1), (b) the time at the moment the driver released the accelerator more than 5% (T_2), (c) the time at the moment the brake was actuated more than 5% (T_3), and (d) the time at the moment of maximum braking (T_4). The following dependent measures were then calculated for the statistical analyses: (a) time headway (THW); (b) preferred time headway (PTH) being the mean time headway for a 1-min segment of the PTH trial; (c) reaction time (RT) calculated as the time between the onset of front vehicle deceleration to the time when the accelerator was released more than 5% ($T_2 - T_1$); (d) open-loop movement time (OLMT), which was the interval between the moment the accelerator was released more than 5% and the brake was activated more than 5% ($T_3 - T_2$); (e) closed-loop movement time (CLMT), being the interval between the moment the brake was actuated more than 5% and the moment of maximum brake position ($T_4 - T_3$); (f) total movement time (MT), which was the sum of the open-loop movement time and closed-loop movement times; (g) response time (RST), given as the interval between the lead vehicle braking onset and the moment of maximum braking ($T_4 - T_1$); (h) time-to-contact at initial deceleration (TTC_1), was the time-to-collision with the lead vehicle (THW divided by the difference between the lead and participant vehicle speeds); (i) time-to-contact at initial braking (TTC_2), which was the time-to-collision with the lead vehicle at T_3; and (j) time-to-contact at maximum braking (TTC_3), which was the time-to-collision with the lead vehicle at T_4.

2.5. Statistical Analysis

All measures were subjected to mixed-model analysis of variance (ANOVA). Participant gender (male vs. female) and athletic status (athlete vs. non-athlete) were between-participant factors and lead vehicle speed was the within-participant factor. Unless otherwise stated, reported degrees of freedom and probabilities for repeated measure effects and associated interactions were adjusted based on the Greenhouse-Geisser epsilon when deemed necessary by a significant Mauchly sphericity statistic. Where appropriate, follow-up tests were conducted using the Tukey comparison, unless otherwise indicated. A traditional level of significance ($p < .05$) is adopted for all parametric testing. One limitation of the statistical model was its inability to handle missing cells in the repetition factor. Missing cells were produced when, for example, participants did not have the accelerator sufficiently actuated at the moment the lead car began braking. In this situation, the simulator could not record a reaction time and this happened on seven occasions. Another concern was the difficulty in applying the desired (strict) athletic status criteria. Some athletes were participating primarily in open-loop pursuits (e.g., swimming), whereas some non-athletes had some varsity high-school sport experience. These concerns are discussed in more detail in section 4.

3. EXPERIMENTAL RESULTS

3.1. Preferred Time Headway (PTH)

Measures of PTH were calculated and subjected to the designed analysis, which indicated that there were no main effects or interactions for either gender or athletic experience. This finding confirmed that preferred headway, which was the baseline condition, was not affected by either of the manipulated factors.

3.2. Response Time

Measures of reaction time (RT), open-loop movement time (OLMT), closed-loop movement time (CLMT), total movement time (MT), and total response time (RST) were calculated and subjected to the designed analysis. Analysis of RT, OLMT, and MT revealed no significant interactions or main effects for gender or athletic status. Analyses of CLMT indicated a main effect for lead vehicle speed, $F(1, 20) = 6.989$, $p < .05$, see Figure 2. As is evident, closed-loop response time was higher with the higher of the two speeds. Analyses of RST also indicated a comparable main effect for lead vehicle speed, $F(1, 19) = 9.738$, $p < .01$. As illustrated in Figure 3, the expected pattern persisted in that higher total response times were associated with higher lead vehicle velocity.

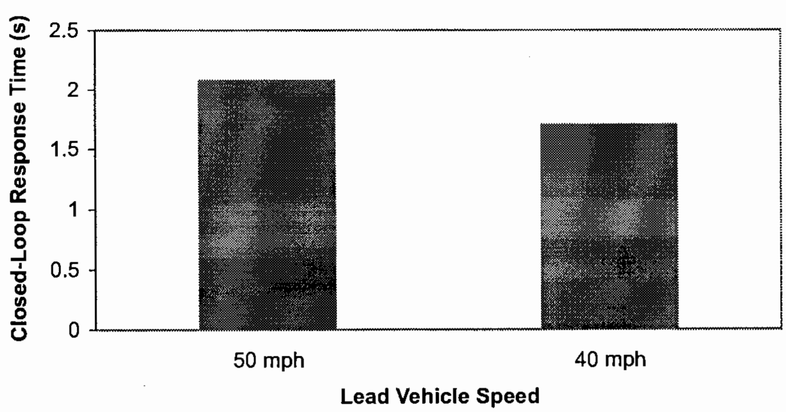

Figure 2. Closed-loop response times at 40 and 50 mph (64.37 and 80.47 km/h).

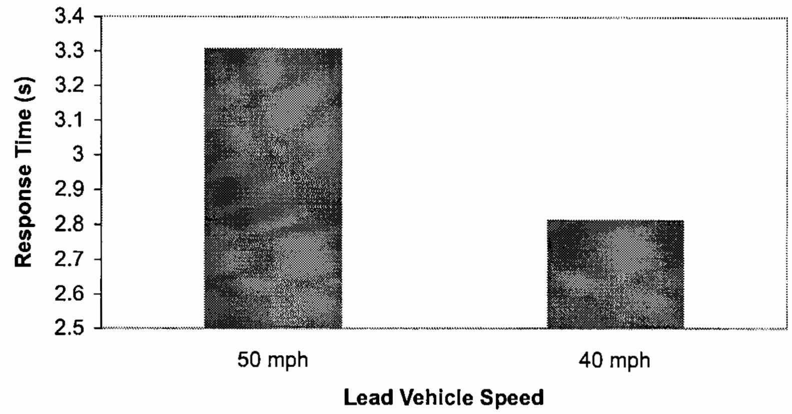

Figure 3. Response times at 40 and 50 mph (64.37 and 80.47 km/h).

3.3. Time to Contact (TTC)

Measures of time-to-contact at T_2 (TTC_1), time-to-contact at T_3 (TTC_2), and time-to-contact at T_4 (TTC_3) were computed and subjected to the designed analyses. Analyses of TTC_3 indicated no significant interactive or main effects. Analyses of TTC_1 indicated a significant status effect, $F(1,16) = 5.524$, $p < .05$. As is illustrated in Figure 4, these data show that those members of the athlete group possessed a significantly higher times-to-contact at the point when the accelerator was released by 5%. Such a result apparently indicates a superior response on behalf of the athletes. Analyses of TTC_2 also indicated a main effect for athletic status, $F(1, 20) = 7.699$, $p < .05$. As is shown in Figure 5, the advantage possessed by the athletes at

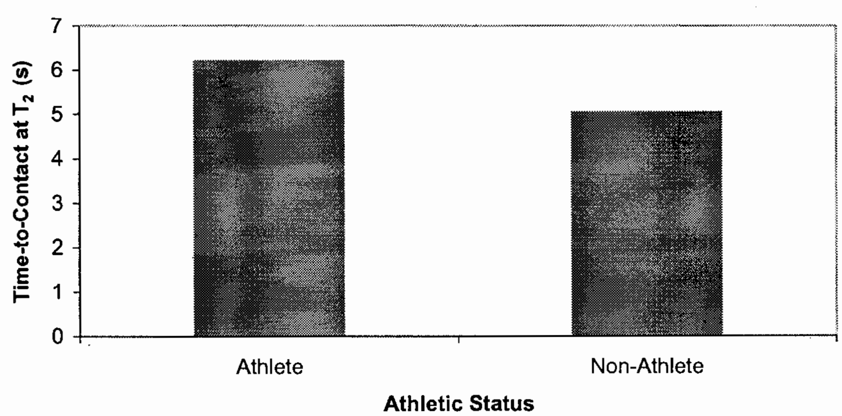

Figure 4. Time-to-contact at T_2 for athletes and non-athletes.

the moment of accelerator release was perpetuated at the point at which the brake was depressed by 5%. This pattern again confirms superior response on behalf of the athletic participation group.

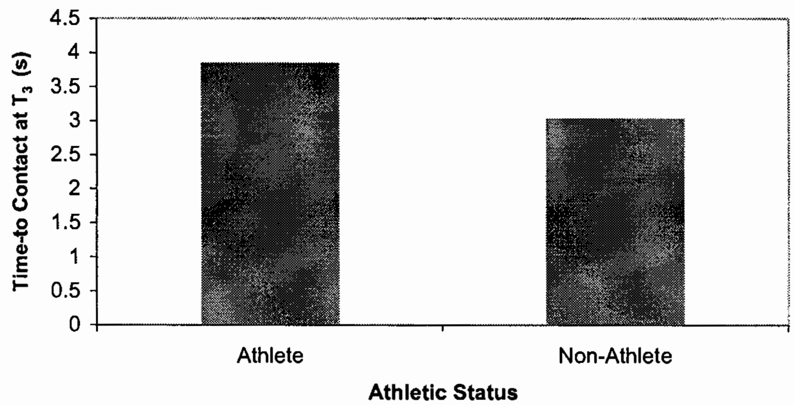

Figure 5. Time-to-contact at T_3 for athletes and non-athletes.

4. DISCUSSION

The results of the study do not support the notion that males and females differed significantly with respect to their driving performance in the conditions described. In addition, the data showed no inherent bias based on either gender or athletic status with respect to preferred time headway. The same was true for behaviors associated with ballistic aspects of response such as reaction time and open-loop movement time. In spite of these findings, athletic status was an important factor in the results for TTC (length of time for the participant's car to contact the lead vehicle): TTC scores indicated a clear performance advantage for athletes over non-athletes. Despite little evidence that behavior differed (i.e., RT, CLMT, OLMT, MT, RST) by athletic status, athletes were able to achieve better (longer) TTC scores. Thus, it appeared that the advantage of athletic participation is not in the ability to behave (move limbs, react), but in the ability to produce desirable performance in context. Furthermore, some descriptive data seem to indicate that the performance gap between female athletes and female non-athletes was wider than the performance gap for their male counterparts. For example, the difference in CLMT scores between female athletes and non-athletes was four times greater than the difference between male athletes and non-athletes at 50 mph (80.47 km/h), and six times greater at 40 mph (64.37 km/h). Similarly, the difference in RST scores between female athletes and non-athletes was twice the difference between male athletes and non-athletes at either speed. (Note: statistical significance was never achieved, probably due to the variability of performance within groups.) For all participants, effects for speed in closed-loop behaviors and total response times indicated longer closed-loop movement times and response times under higher speeds, probably due to the fact that the two vehicles were farther apart at the higher speed. This is indicative of a poor driving strategy. Despite differences in distance, time-headway was kept constant, thus the longer CLMTs and RSTs under the higher speed actually reduced the separation between vehicles.

4.1. Practical Recommendations

These results suggest that athletic participation does provide an advantage in certain aspects of driving performance. Furthermore, the findings indicate that sports participation has the potential to provide a significantly greater effect for females in terms of improving driving performance. These patterns of findings suggest that an important segment of the driving population, females in general, and older females in particular, could increase their ability to avoid accidents by engaging in activities such as sports that improve perceptual-motor competence. Consequently, we propose the following recommendations:

- Further evaluate potential differences with a more particular focus upon the type of athletic experience. Given the transfer of training literature, it is probable that particular types of activities (i.e., team vs. individual sports; activities requiring open vs. closed motor skills and gross vs. fine motor control) mediate transfer to driver competence.
- Results suggest that the gap in performance differences were greater between female athletes versus female non-athletes than it was for male athletes versus male non-athletes. This may be that due to sociocultural differences.
- Advocate the inclusion of perceptual-motor tasks, especially training for practice in unusual driving circumstances (e.g., emergency collision avoidance) in the licensing procedures, particularly for novice and elderly drivers.

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