Is There a Bilingual Advantage When Driving and Speaking Over a Cellular Telephone?

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One of the most common dual task challenges involves driving while speaking on a cellular telephone. Bilingualism provides performance advantages in dual task paradigms involving divided attention, compared to monolinguals. It was hypothesized that bilinguals should demonstrate performance advantages when driving and performing a variety of verbal tasks into a simulated hands-free cellular telephone compared to monolinguals. 82 university students participated in the study following assessment of their linguistic fluency. The driving task was performed on the driving simulation program Drivesim 4.00 and the experiment consisted of both single driving and speaking conditions, as well as dual conditions with both driving and speaking tasks. Bilinguals demonstrated significantly fewer decrements to their driving performance when speaking on a cellular telephone compared to monolinguals, providing a practical demonstration of the cognitive advantages of bilinguals in dual task paradigms.

Key words: Bilingualism, Cellular telephone use, Driver safety.

INTRODUCTION

With the advancement of vehicle informatics (e.g. GPS receivers, e-mail, satellite radio, mobile telephones, etc.), multitasking challenges have become common for vehicle operators. One of the most common and controversial dual task challenges involves driving while speaking on a cellular telephone. Research in Canada has suggested that when using a cellular telephone while driving, the risk of having a collision involving severe injury to the driver is increased by 38% (Redelmeier & Tibshirani, 1997). Further, the driver using a cellular telephone is 16% more likely to have caused the collision (Rakauskas, Rakauskas, Gugerty, & Ward, 2004). The reasons for increased collision risk may reside in the riskier driving behavior of cellular telephone users, independent of when they are using their cellular telephones while driving (Wiesenthal & Singhal, 2005). Second, driver performance while engaging in a conversation on a cellular telephone may be impaired by diverting attention away from driving to the cellular telephone conversation. The detrimental performance effects of cellular telephone conversations during vehicle operation have been supported by numerous empirical studies (see Wiesenthal & Singhal, 2005 for a review of the literature).

Bilinguals (i.e. people who speak two languages fluently) have been shown to possess cognitive and performance advantages in attention demanding multi-tasking laboratory situations compared to monolinguals (people who speak only one language fluently). Although a large amount of research has found that driving performance is impaired when speaking over a cellular telephone compared to when driving without using a cellular telephone, researchers had not yet examined whether bilinguals due to their cognitive advantages might be more resistant to distraction when speaking over a cellular telephone compared to monolinguals. This research has relevance to the numerous multicultural cities in the United States where there are large numbers of people who are fluent in two languages such as Spanish and English, as well as the province of Quebec, Canada that has a high percentage of residents who are considered bilingual. In the province of Quebec, it has been estimated that over 40% of the population are able to speak at least two languages fluently (Statistics Canada, 2001).

Bilinguals and Dual Task Performance

In general, individuals who speak two languages fluently have been shown to perform better in attention-demanding dual task paradigms compared to monolinguals who only speak one language fluently (Bialystok, Craik, & Ruocco, 2005; Ransdell, Arecco, & Levy, 2001). The attentional advantages of bilinguals compared to monolinguals in dual task paradigms have been attributed to their more advanced executive control processes for managing their two active languages (Bialystok et al., 2005). Bialystok and her associates (2005) proposed that in bilinguals both languages remain continuously activated. When speaking or processing one language, a bilingual must inhibit their other active language so that it does not intrude on their selected language.

Bialystok et al. (2005) used a dual task paradigm to investigate whether younger and older adult bilinguals have enhanced monitoring and switching capabilities compared to monolinguals. All the bilinguals were completely proficient in both English and their second language, used both of their languages daily, and learned their second language before the age of ten as assessed by a background questionnaire and measures of speaking vocabulary. Participants were required to perform both an auditory and a visual classification task simultaneously. The visual task was the primary task, and performance was measured on the visual task while performing a secondary auditory task, compared to the single visual task. The bilingual group significantly outperformed the monolingual group in the dual task condition only when the visual task was the primary task. The researchers concluded that more experience in monitoring two languages might strengthen executive control processes involved in such dual tasks requiring divided attention.

Hypotheses

There were three major hypotheses of the present research regarding the independent variables of driving condition and language group and the dependent driving measures of driving performance. First, the manipulation of driving condition from driving without speaking to speaking English over a simulated hands-free cellular telephone when driving will result in significantly poorer driving. Second, the bilingual group will demonstrate significantly better driving performance than monolinguals when driving and speaking over a simulated hands-free cellular telephone due to their cognitive advantages in dual tasks.

METHOD

Participants

A total of 82 students that were attending a large Canadian university participated in the study following assessment of their linguistic fluency. The participants were recruited from undergraduate classes and were compensated $20 for their participation. The participants consisted of 35 monolinguals and 47 bilinguals. All participants had at least two years of driving experience and the majority of participants were between 18-30 years of age. The numbers of highly proficient video-game players as assessed by a video-gaming questionnaire were controlled so that their proportions were equally distributed between the two language groups.

Equipment

Driving simulator. The driving task was performed in a virtual driving environment on the computer program Drivesim 4.00 of the York Driving Simulator (York Computer Technologies, Kingston, Ontario, Canada, http://www.yorkdrivesim.com/). The York Driving Simulator (YDS) as shown from a screen shot in Figure 1 is a low cost, graphics based, vehicle simulator designed to run on a personal computer. YDS is uniquely adaptable to support both data collection and off-line analysis. The simulator's design also includes a User-Configurable Environment Construction Module, including a comprehensive library of international graphic images related to standard traffic control and warning signs, allowing custom scenarios to be easily programmed. The YDS can be used as a laboratory analogue for testing predictors of performance or as a test of performance, where it is capable of measuring a variety of driving performance measures. It presents a forward view from the driver's seat of a motorway road scene, with standard lane markings, signs, and signals suitable to the driving environment (Arnedt, Wilde, Munt, & Maclean, 2000). The YDS has been previously used by Arnedt, Acebo, Seifer, & Carskadon (2001) and Arnedt, Wilde, Munt, & Maclean (2000) as an effective and naturalistic research tool to measure psychomotor performance. The YDS simulator used in the present study ran on a Hewlett Packard Pentium 4 3.07 GZ computer with hyper threading technology, 1GB of RAM, Windows XP, an integrated ATI Radeon Express 2GB series video card that was OpenGL compatible, separate monitors for the participant and the experimenter, and a Logitech NASCAR steering wheel, accelerator, and braking system (Logitech, 2004, http://www.logitech.com/).

Research Design

Driving scene and routes.

Figure 1. Braking event screen shot from the York Driving Simulator.

The driving routes consisted of two-lane divided highways with both straight and curved sections of roadway. The driving scenes consisted of simulated traffic, trees, and changing speed and road signs. A total of six different driving routes of approximately equal difficulty, along with six different driving scenarios comprising equivalent combinations of traffic events were randomly assigned to participants and experiment conditions during the experiment. The traffic events consisted of approximately equal numbers of braking, slow moving, passing, lane changing, and stationary cars that were assigned in a randomized order across driving scenarios. The dependent measures of driving expressed as a mean value over each 3 minute driving scenario were lane deviation, expressed as the deviation of the center of the car from the right edge of the road in meters, speed deviation, measured as the deviation from the posted speed signs in km/h, number of crashes, and a safety measure called safe driving, expressed as a percentage of time during the driving scenario that the participant was remaining within a safety box placed horizontally 1 meter to either side of the center of their lane, and vertically at 10 km/h above and below the posted speed limit. The simulator program sampled these performance variables 10 times per second.

Verbal Tasks

To assess more generative versus receptive components of speech, four different verbal tasks, taken from standardized tests of cognitive ability, were presented as simulations of different types of conversations. Generative components of speech involved producing novel speech, whereas receptive aspects involved listening to and repeating speech. These verbal tasks provided simulations of cellular telephone conversations of variable levels of intensity, with vocabulary and working memory tasks being more intense, requiring generative conversations, and story and sounds tasks constituting less intense conservations and being more receptive in nature. The vocabulary task required participants to verbally explain the meanings of different words that gradually increased in complexity. The story task required the participants to listen to stories that gradually increased in length and then verbally recall as many details of the stories that they could remember. The sounds task required participants to blend a series of sounds together that gradually increased in number into words and then vocalize the correct word. Finally, the working memory task required participants to listen to a series of words and numbers, with the sequences gradually increasing in number. After hearing the sequence, participants were required to verbally sequence the words in their correct order followed by the numbers, both in the orders in which they were heard.

Experiment Design

The task conditions for the experiment consisted of control conditions of driving and speaking, as well as experimental conditions of driving with each of the verbal tasks. The conditions were counterbalanced using two Latin squares. Table 1 shows the first Latin square used for the experiment. The second Latin square had the same configuration as the first Latin square with control sounds and memory tasks and dual sounds and memory tasks instead of story recall and vocabulary tasks as used in the first Latin square. Each level of task condition was randomly assigned to the designated letters for both Latin squares. Each Latin square had five sequences of presentation. The order of receiving either the first Latin square of condition sequences (Table 1) or the second Latin square of condition sequences was further counterbalanced for a total of ten condition orders that assessed either control driving performance, control speaking performance, or both speaking and driving performance as dual tasks. Approximately eight participants were randomly assigned to each sequence for a total of 82 participants.

Table 1. Experimental design and Latin square for task condition counterbalancing of first series of sequences.

Task condition		
Control	Dual Story	Dual Vocabulary
Driving (A) Verbal (Story recall) (B) Verbal (Vocabulary) (C)	(D)	(E)

	Testing position
Sequence 1	A B E C D
Sequence 2	B C A D E
Sequence 3	C D B E A
Sequence 4	D E C A B
Sequence 5	E A D B C

Procedure

Participants were first administered a demographics questionnaire soliciting information such as their age, sex, proficiency and frequency of use of their first and second languages, and proficiency and frequency of playing high speed video games. Participants were then administered the Picture Peabody Vocabulary Test Third Edition Revised (Dunn, Dunn, Robertson, & Eisenberg, 1981), to measure English speaking vocabulary ability as an additional measure of their fluency in English. Participants then watched a short training module on the driving, verbal, and dual task conditions. Participants were given 15-minutes of training on the driving task and pilot work established criteria on three of the four driving measures for eligibility to proceed. For the driving conditions, participants were instructed to drive in the right lane at the posted speed limits and change lanes only to pass slower vehicles. For the verbal conditions, participants were instructed to respond accurately and quickly into a microphone after hearing a “beep” that signaled the end of the stimulus. For the dual task conditions, participants were instructed to drive the vehicle as in the control driving conditions while remaining engaged in the verbal tasks as much as possible.

RESULTS

Separate five (driving condition) X two (language group) mixed model ANOVAs were applied to the dependent driving measures with the independent measure of driving condition as a repeated measures factor and the independent measure of language group as a between group’s factor.

Driving Performance While Talking on a Cellular Telephone Versus Control Driving

Due to the fact that two different control-driving conditions were used in the experiment, one in the first series of tasks and one in the second series, the mean of both control-driving conditions was used in the test of condition effects. A significant main effect of driving condition was found on the percentage of time driving safely across both language groups, F (6, 474) = 35.70, p<0.001. The η^2_p was large at 0.25. Bonferroni post hoc comparisons revealed that control driving (M = 55.92 %, SD = 15.77) resulted in significantly higher percentages of time driving safely than when driving with sounds (M = 41.77 %, SD = 14.62), working memory (M = 41.77 %, SD = 16.41), story listening (M = 42.64%, SD = 17.41), and vocabulary tasks (M = 43.34 %, SD = 15.73) across all language groups, p<0.001. This supported the first hypothesis of the study in that driving when conducting a verbal task over a hands-free cellular telephone resulted in significantly poorer driving performance than when simply driving. The dual conditions of driving with the cellular telephone verbal tasks were not significantly different from each other. The language by condition interaction was also not significant. A significant main effect of condition was also found on the number of crashes, F (6, 242) = 2.46, p<0.05. Control driving conditions (M = 0.70 crashes, SD = 1.01) were found to have significantly fewer crashes that the condition of driving with the vocabulary task (M = 1.17 crashes, SD = 1.23). Conditions of control driving were not statistically different from conditions of driving with the verbal tasks for the measures of speed deviation (km/h) and lane deviation (m), p > 0.05 for both comparisons.

Effects of Bilingualism

Control driving conditions and driving with verbal task conditions. Bilinguals (M = 51.86%, SD = 15.29) were found to have a significantly lower percentage of time they drove safely in the control driving conditions than monolinguals (M = 61.26%, SD = 2.56), F (1, 121) = 8.01, p<0.01, but not when driving with the cellular telephone task. The monolingual and bilingual groups did not differ significantly in their number of crashes in both the control driving condition, p>0.05, and driving conditions with the verbal tasks, p>0.05. For the amount of speed deviation, monolinguals and bilinguals did not differ in their amount of speed deviation in both the control driving and driving with verbal task conditions, p>0.05 for both comparisons. For the amount of lane deviation, bilinguals (M = 2.30 m, SD = 0.30) were found to have significantly greater lane deviation than monolinguals (M = 2.14 m, SD = 0.20) in the control driving condition, F (1, 79) = 5.69, p<0.05. For the conditions of driving with the verbal tasks, monolinguals and bilinguals did not differ significantly in their amounts of lane deviation, p>0.05.

Driving performance decrements scores. Given that monolinguals and bilinguals had significantly different driving performance for the percentage of time driving safely and the amount of lane deviation in the control driving conditions, it was not sufficient to only examine significant differences in absolute driving performance while conducting the cellular telephone tasks to determine whether driving with the verbal tasks would be any worse for a particular language group. Performance decrement scores were computed in order to establish a difference score between each driving condition conducted with a cellular telephone task and the second control driving condition for each participant and for each driving measure. This was done to determine whether monolinguals had suffered greater decrements to their driving performance due to the cellular task relative to their baseline driving compared to bilinguals. Using the second control driving condition provided greater assurance that all participants had received sufficient practice on the driving task, especially the bilingual group which had taken longer to learn the driving task. The formula used to compute the decrement for each participant and for each driving measure was therefore:

Performance decrement = Second control driving condition performance- Driving performance with cellular telephone. **(1)**

As shown below in Figure 2, there was a large effect of language group on the decrement scores for the percentage of time driving safely, F (1, 79) = 6.69, p = 0.01, η^2_p = 0.08.

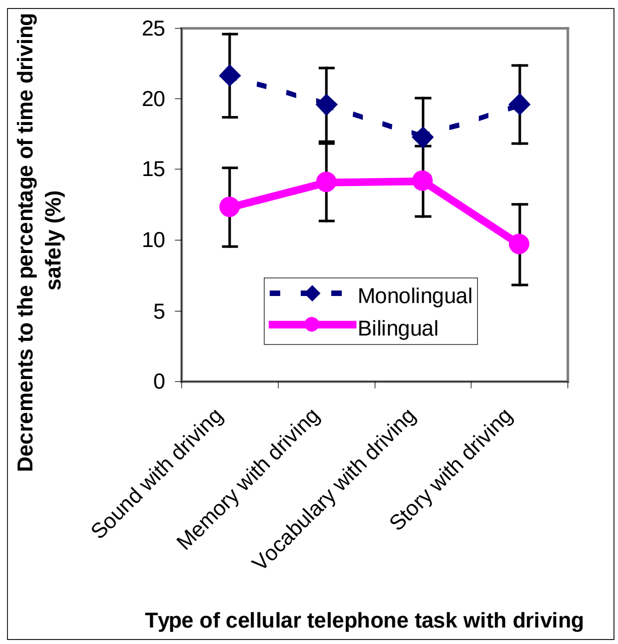

Figure 2. Mean decrements to the percentage of time driving safely for each cellular telephone task with driving. The error bars indicate the standard error of the mean.

Bilinguals (M = 12.57 %, SD = 1.96) had significantly smaller decrements to their percentage of time driving safely when switching from control driving to driving with the cellular telephone tasks compared to monolinguals (M = 19.52%, SD = 2.31), p = 0.01. There was no main effect of cellular telephone task condition on the decrements to the percentage of time participants drove safely. The condition by language group interaction was also not significant. Decrement scores were also computed for the amount of lane deviation between monolinguals and bilinguals given the differences in lane deviation that were found between these groups in the control driving conditions. Bilinguals failed to show significantly fewer decrements in lane deviation between conditions of driving with the verbal tasks and control driving compared to monolinguals, $p>0.05$.

DISCUSSION

The results of the present study supported numerous studies that have demonstrated cognitive detriments on driving performance from speaking over a hands-free cellular telephone (Rakauskas, Gugerty, & Ward, 2004; Strayer, Drews, & Johnson, 2003; Strayer & Johnson, 2001). The second hypothesis of the study was also supported; bilinguals demonstrated a relative advantage in terms of their ability to obtain smaller decrements to the percentage of time they were driving safely (remaining within their safety box) when transitioning from control driving to driving with a simulated cellular telephone compared to monolinguals, who's driving performance decreased to a larger extent relative to their own baseline driving. Given that the control driving conditions were counterbalanced for both monolinguals and bilinguals this performance advantage was most likely not due to practice effects. The monolingual group dropped an additional 5% in their percentage of safe driving from the control driving condition to the driving conditions with the verbal tasks compared to the bilingual group. Whether this difference has practical safety implications beyond the lab is difficult to determine given the novelty of the research and driving simulator that was used. In difficult driving situations or on busy roads or highways this 5% relative difference in performance might have substantial safety implications for drivers in terms of how much there driving performance may worsen due to their linguistic characteristics, where being bilingual may offer some advantage.

This is the first study examining the relative performance advantages that bilingualism provides when transitioning from driving in the absence of a cellular telephone to driving while speaking over a cellular telephone. The current research has highlighted the potential performance advantages and safety benefits from speaking two or more languages fluently in common dual task situations such as driving with mobile devices. Additional research is needed to examine how the linguistic characteristics of the driver affect their ability to drive as well as drive when speaking on a cellular telephone. Researchers who are conducting laboratory research, as well as epidemiological studies on the detriments of cellular telephone use and driving need to further examine driver errors and inattention related to the linguistic characteristics of drivers when speaking on cellular telephones while driving. Even researchers, who are not specifically investigating the issue of language, cellular telephone use, and driving, should take into consideration the linguistic characteristics of the driver when exploring the relationship between cellular telephone use and driving. The opportunity to learn multiple languages may result in numerous cognitive advantages applied to practical and cognitively challenging environments.

Future research should make use of a higher fidelity-driving simulator with more realistic graphics and controls, as well as use real conversations with confederates. The risk of injury to the driver however, can never be recreated and is one of the shortcomings of simulator-based driver research.

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REFERENCES

Arnedt, J.T., Acebo, C., Seifer, R., & Carskadon, M.A. (2001). Assessment of a simulated task for sleep research. *Sleep, 24S:A413*

Arnedt, J.T., Wilde, G.J.S., Munt, P.W., & Maclean, A.W. (2000). How do prolonged wakefulness and alcohol compare in the decrements they produce on a simulated driving task? *Accident Analysis and Prevention*, *27*, 707-715.

Bialystok, E., Craik, F., & Ruocco, C. (2005). Dual modality monitoring in a classification task: The effects of bilingualism and aging.

Dunn, L.M., Dunn, L.M., Robertson, G.J., & Eisenberg, J.L (1981). Peabody *Picture Vocabulary Test III Revised*. Circles Pines, MN: American Guidance Service.

Rakauskas, M.E., Gugerty, L.J., & Ward, N.J. (2004). Effects of naturalistic cell phone conversations on Driving performance *Accident Analysis and Prevention*, *35*, 453-464.

Randsdell, S., Arecco, M.R., & Levy, C.M. (2001) Bilingual long- term working memory: The effects of working memory loads on writing quality and fluency. *Applied Psycholinguistics*, *22*, 113-128.

Reidelmeier, D.A., Tibshirani, R.J. (1997). Association between cellular telephone calls and motor vehicle collisions. *The New England Journal of Medicine 336 (7), 453-458.*

Statistics Canada. *Census of Canada 2005*. Retrieved November 8, 2005, from http://www12.statcan.ca/english/profil01/ CP01/SearchForm

Strayer, D.L., Drews, F.A., & Johnston, W.A. (2003). Cell phone induced failures of visual attention during simulated driving. *Journal of Experimental Psychology: Applied*, *9*, 23- 32.

Strayer, D.L., & Johnston, W.A. (2001). Driven to distraction. Dual-task studies of simulated driving and conversing on a cellular telephone. *Psychological Science*, *12*, 462- 466.

Wiesenthal, D.L., & Singhal, D. (2005). Is it safe to use a cellular telephone while driving? In D.A. Henessey and D.L. Wiesenthal (Eds.). *Contemporary issues in road user behavior and traffic safety. Hauppage, NY:* Nova Science Publishers