DIVIDED ATTENTION BETWEEN VISUAL AND AUDITORY STIMULI: IMPLICATIONS FOR CELLULAR TELEPHONE USE WHILE DRIVING

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I am submitting herewith a thesis written by Tiffanie Markus entitled "Divided Attention between Visual and Auditory Stimuli: Implications for Cellular Telephone Use While Driving." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Psychology.

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ABSTRACT

To examine the possible effects of driving while using a mobile telephone, 31 participants were tested using a divided attention task. The task consisted of a visuo-motor component and an auditory component. While participants spent proportionately less time on target during the presence of a distracter requiring a motor response (red trials), the auditory component had no effect. There were significantly more slips off target during the red trials. There was also a significant interaction between the distracter and the auditory condition on slips off target.

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CHAPTER I

Introduction

Technology is advancing at a rate that is hard to follow: each year bringing new ideas, new devices, and better methods of communication. People can now communicate with others around the world almost instantaneously and at almost any time or place.

The mobile phone is one such device being used to increase the availability and the amount of communication. It was estimated in 1993 that approximately 16 million mobile phones were in use in the United States and that number has undoubtedly increased significantly in the past six years (Hagan Associates, 1996). The mobile phone can be a useful tool in facilitating communication concerning anything from business to emergency assistance. However, when used while driving, the mobile phone may become a contributor to the need for emergency assistance.

The ability to operate an automobile successfully may be disrupted by the use of mobile phones. In 1993, approximately 35% of traffic accidents in the state of New

York were attributed to "driver inattention" (New York State, Department of Motor Vehicles Statistical Reports, 1993). Inattention has been labeled as one of the foremost contributors to traffic accidents, exceeding other factors such as control and response errors (Treat et al., 1977). Mobile phones may cause drivers to be distracted from the vigilance task of operating an automobile.

Previous research indicates the act of dialing a number on a mobile phone leads to a decrement in driving performance. One motor response takes precedence over the other. For example, when dialing a number, an individual might be required to interrupt the operating of the automobile to locate the appropriate buttons on the phone (McKnight & McKnight, 1993; Stein, Parseghian & Allen, 1987). The present investigation focused on the effects of dividing attention between tasks similar to driving an automobile and those similar to conversing on a mobile phone.

CHAPTER II

Literature Review

Divided Attention

The term "attention" is often used synonymously with terms such as divided attention, sustained attention, and vigilance. Mackworth (1957) has defined vigilance as "a state of readiness to detect and respond to certain specified small changes occurring at random intervals in the environment" (p.389). Vigilance is usually studied with tasks that require attention to be focused on detecting a stimulus and then responding appropriately. A decrease in vigilance leads to decrements in performance and accuracy. According to Weinberg and Harper (1993), vigilance may decrease due to numerous variables including the nature of the stimulus, distractibility, and diligence.

Both operating an automobile and conversing on a mobile phone are vigilance tasks. While driving, individuals are required to attend to the environment surrounding them and to be ready to respond to changes in driving conditions. An example would be depressing the brake pedal when the vehicle ahead appears to be decelerating. Likewise, carrying on a conversation also requires some level of vigilance to be able to comprehend the intended message and make the appropriate verbal responses.

Resource Models

According to resource models, attention may be limited by the amount of information that can be managed by the available resources. When resource demands surpass the amount of resources available, performance will deteriorate. According to Proctor and Zandt (1994), Kahneman's (1973) resource model presents attention as a limited-capacity resource that can be utilized in numerous situations. Simply executing two tasks simultaneously is not necessarily difficult unless the amount of resources needed to perform the two tasks surpasses the amount that is available. In that case, performance will suffer and therefore, a criterion must be set by the brain as to how much attention will be allocated to the two concurrent tasks to efficiently complete both simultaneously.

Posner and Boies (1971) looked at dual-tasks and how performance is affected by resource availability. The criteria for dividing attention will depend on the nature of each task and the cost of not giving complete attention to each. Performance on the primary task will consume the necessary amount of resources for adequate performance and the secondary task will receive the surplus resources. If the primary task requires all available resources, none will be available to the secondary task and performance will suffer on that particular task.

The resource model indicates that a primary task, such as driving, will consume the necessary amount of resources to maintain adequate driving performance. Therefore, the introduction of a secondary task, such as talking on a mobile phone, will only receive leftover resources and performance on this task should deteriorate. However, this situation could be quite dangerous if talking on a mobile phone becomes the primary task, leaving the task of driving with an inadequate amount of resources.

The Postponement Model

A second possible theory to explain how performance is affected on dual-tasks is the postponement model. This model suggests that the response for the secondary task is not processed until the response for the primary task has been selected. This is not the case for perceptual processes. It appears that while the secondary response has to wait for the primary response to be processed, perception of the secondary stimulus occurs immediately (Pashler, 1991).

A primary task, such as driving an automobile, could be held in higher regard than a secondary task of having a conversation on a mobile phone. However, driving under normal conditions usually requires very little concentration because the task has become automatic. A phone conversation, on the other hand, is most likely providing novel information and requires more attention to process the intended message. In actuality, the phone conversation may become the primary task. If this is the case, according to the postponement model, a response to a change in driving conditions will have to wait to be processed until the response to the conversation has been processed.

An investigation by Brown, Tickner and Simmonds (1969), predating the widespread use of mobile phones, addressed the issue of the effects of divided attention on clearance judgements, control skills, and checking an auditory message. Participants were asked to listen to a set of reasoning conditions and decide whether the target satisfied that condition. An example of this would be a condition of "A follows B," then a target of "BA" with the correct response being "true." As they listened to the conditions and made verbal responses, they had to decide if the automobile they were driving on a road course could fit through various obstacles. Some obstacles were wide enough for the vehicle to pass, while others were too narrow. Participants made more errors in judging the gaps when using a mobile phone. Under the divided attention task they tried to drive through more gaps that were too narrow. Participants also slowed down their driving speed and took longer to complete the course.

The participants' decision to decrease speed on the road course may have been used to increase the amount of time to process the information from both tasks as part of their criterion for dividing attention. However, decreasing speed did not prevent the interference of the dual-task. In fact, as driving time increased so did the number of judgement errors. Results from this study support the idea that while mobile phone use does not significantly affect the motor control of the vehicle, it does impair perception.

Traffic Safety

Violanti (1997) used a statistical approach to assess differences in the number of traffic accidents with and without the presence of mobile phones. Information was accumulated from 206,639 traffic reports in the state of Oklahoma over a three-year period. A total of 5,292 drivers were reported as having a mobile phone in the vehicle at the time of the accident; 492 of those were reported as actually using the phone at the time of the accident. In 1992, the percentage of people possessing a mobile phone at the time of the accident was 19% and that number grew to 32% in 1995. When considering the types of accidents involved, the accident reports showed that individuals possessing phones had significantly higher rates of driving at unsafe speeds, inattention, inability to stay in the appropriate lane, overturning their vehicle and hitting stationary objects.

Males and older individuals had higher accident rates. Eighty-nine percent of driver fatalities were males. Those involved in fatal collisions, compared to non-fatal collisions, were on average at least 40.5 years old (Violanti, 1997; Violanti, 1998). Ponds, Brouwer, and van Wolffelaar (1988) also found that older (over 60 years) subjects' performance declined more during a dual-task and attributed this to a reduction of attentional capacity. Violanti added in his 1998 investigation that people who were reported as using a phone during the accident had a nine-fold risk of dying as a result of the accident over those not using a phone.

Violanti and Marshall (1996) used a similar approach, but in addition to traffic reports they obtained phone records and mailed driving behavior surveys to individuals with and without accidents on their driving record. Individuals with accidents on their records spent approximately twice as much time on the mobile phone per month as those who had not had an accident. Individuals who talked on the phone for more than 50 minutes per month were found to have a 5.59-fold risk of having an accident compared to those spending less time on the phone.

These studies show circumstantial evidence that mobile phone use is related to the likelihood of having a traffic accident. It is also crucial to consider the limitations involved in the use of data from traffic records. There is no direct evidence that those with phones were actually using them at the time of the accident and the presence of a phone may have been overlooked by the officer and consequently not reported. Other distracting activities, such as eating, drinking, reading or daydreaming could have been a factor in causing these accidents. Additional factors could have come into play, such as the number of miles driven per year or the amount of risk taking behaviors.

McKnight and McKnight (1993) investigated the effects of mobile phone conversations on attention to a driving task. A simulated driving task was used with a hands-free phone scenario containing either a casual or an intense message. Other conditions such as tuning a radio and dialing a phone number were added for a motor response competition comparison. All conditions containing a phone or a radio component had an effect on the individuals' ability to make appropriate responses to changes in traffic. The effects of intense conversation proved to have the greatest impact, followed by casual conversation. Tuning the radio on was as distracting as the intense conversation. Thus, an intense conversation has the same consequence as taking your eyes off the road to locate a radio station.

In summary, judgement errors increase with mobile phone use, conversation causes decrements in performance and time spent on a mobile phone is associated with a risk of having a fatal accident. This provides some evidence that divided attention can have a detrimental effect on driving performance.

Present Study

The present investigation was designed to measure divided attention between a visuo-motor tracking task and an auditory task. The auditory task had three levels of intensity, based on the findings of McKnight and McKnight

(1993) that casual and intense conversations decrease driving performance with intense conversations showing a more profound decrement. Also, responses to the auditory stimuli were made verbally as opposed to performing a motor response to decrease the confound of one motor response interfering with another, visuo-motor, task. A verbal response more closely simulates an actual phone conversation (McKnight & McKnight; Stein, Parseghian & Allen, 1987).

The visuo-motor task of operating an automobile was simulated by the use of a pursuit-tracking task. As mentioned previously (Violanti 1997, 1998), attending to an auditory task increases the occurrence of inattention and swerving out of appropriate lanes while driving. A tracking task should be prone to similar errors when dividing attention. A secondary visual component was randomly introduced to measure differences in response times under the different auditory conditions. This secondary component was intended to simulate a change in traffic conditions (i.e., brake lights, pedestrian) that requires a quick response.

Dual-task procedures allow the attentional demands of each separate task to be calculated. This can be useful when trying to determine the complexity of a task alone and when combined with other tasks. This type of procedure also allows for the prediction of future performance. During a divided attention task in which performance decreases, the decrease can be a result of failure to perceive the target, a decrease in response times or an increase in detection thresholds (Proctor & Zandt, 1994). These can be very costly performance trade-offs when considering the seriousness of failing to operate an automobile properly.

Hypothesis

The auditory task was expected to cause a decrease in performance on the tracking task, with the auditory condition requiring a verbal response having the greatest effect. Also, the response time to the secondary visual target was expected to increase during the condition requiring a verbal response.

CHAPTER III

Method

Participants

The sample consisted of 31 participants from Austin Peay State University's undergraduate psychology courses and staff, with an average age of 31.0 years (ranging in age from 18 to 54 years). The sample was made up of 19.4% males and 80.7% females. Fifty-four percent owned a cell phone with 42.0% using them while they drive, and at a self-reported average of 130 minutes a month.

Apparatus

The visuo-motor task was a computerized pursuit-tracking task, presented using a program created by Dr. Anthony Golden (Austin Peay State University, Psychology Department, Clarksville, TN 37044). The primary target stimulus moved in a predictable, rectangular pattern. The participant was required to track the target with a cursor arrow controlled by a standard mouse. A secondary target was randomly introduced on the computer screen such that the participant was required to rapidly respond to the new stimulus, by deciding whether or not to click the left mouse button while continuing the pursuit task. The visual task was divided into two conditions. One condition contained a randomly presented secondary target that was a red circle and required a left mouse click. The second condition randomly presented a green circle and required no mouse click.

The auditory task involved the use of a headset to present verbal stimuli. Three separate auditory conditions were utilized. One condition had no verbal stimuli (noise condition) and therefore required no response. The second condition contained a simple statement and required no response (no answer condition); for example "There are four main food groups." And a third condition contained information requiring the participant to comprehend the message and make a verbal response (answer condition). For example the participant would hear "Answer. Who was the first president of the United States?"

Procedure

Each participant was given verbal instructions and was asked to read and sign an informed consent statement and a brief demographics questionnaire. A 3 x 2 factorial design was used. A total of 15 trials were presented, in random order, of each of the six combinations of secondary targets and auditory conditions. The entire testing session lasted approximately 25 minutes.

Tracking task performance was measured by the amount of time the cursor stayed in contact with the target and the number of target boundary crossings made by the cursor during each condition. Response latencies to the secondary target were measured during those trials requiring a mouse click.

CHAPTER IV

Results

An analysis of variance was used to examine the effects of the auditory stimulus conditions on time on target. Because trial lengths varied, the time on target was converted to the percent of time on target during each trial. Participants spent proportionally less time on target during presentation of the red secondary target (M = 81.3%), $F(1, 30) = 6.2$, $p<.05$, than while the green target was present (M = 88.4%). However, the auditory conditions had no significant effect on tracking performance, $F(2, 60) = 1.2$, $p>.05$ (Table 1).

TABLE 1

PERCENT OF TIME SPENT ON TARGET DURING ACTUAL TRIALS

Source	df	MS	F	p
Total	185			
Between Subjects	30	1292.7		
Within Treatments	155	106.9		
Red/Green (A)	1	2367.7	6.2	<.05
Error	30	381.1		
Noise Condition (B)	2	31.4	1.2	
Error	60	25.3		
A x B	2	39.9	2.1	
Error	60	18.7		

The frequency with which the participant crossed the target boundary differed significantly for the red and green target stimulus conditions, $F(1, 30) = 26.5$, $p<.001$ (Table 2). There were significantly more target boundary crosses during trials with the presentation of a red secondary target. There was also a significant interaction between the presentation of the red and green secondary targets and the auditory condition, $F(2, 30) = 5.2$, $p<.005$ (Figure 1).

TABLE 2

THE MEASURE OF TARGET BOUNDARY CROSSES PER SECOND OF TRIAL TIME

Source	Df	MS	F	
Total	185			
Between Subjects	30	0.1		
Within Treatment	155	0.02		
Red/Green (A)	1	0.7	26.5	< .001
Error	30	0.03		
Noise Condition (B)	2	0.01	1.0	
Error	60	0.01		
AxB	2	0.05	5.2	< .005
Error	60	0.01		

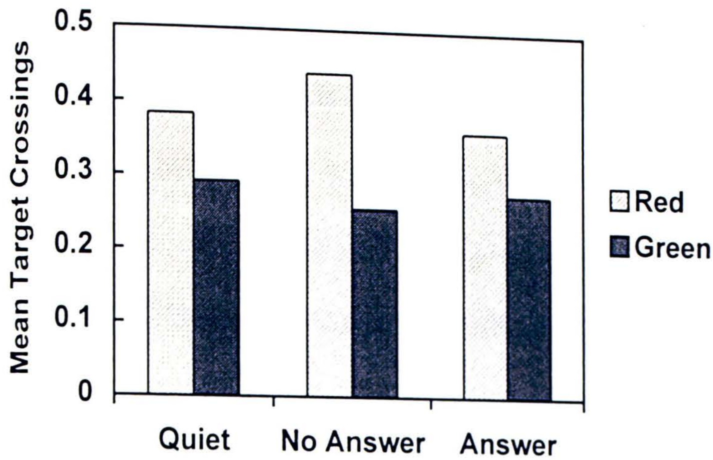

Figure 1. Interactive effect of red and green secondary targets and the auditory condition on target boundary crosses per second.

Post hoc analysis of this interaction using paired t-tests, indicated that responses to the red secondary target were significantly affected under both the "no answer," $\underline{t}(30) = 5.6$, $\underline{p} < .001$, and "answer," $\underline{t}(30) = 3.276$, $\underline{p} < .05$, auditory conditions. However, no performance decrement was seen during presentation of the green secondary stimulus, $\underline{p} > .05$. The probabilities for the t-tests were subjected to the Dunn-Sidak adjustment to compensate for the number of comparisons being performed.

As can be seen in Table 3, there were no significant differences found in the response latency during the presentation of red secondary targets $\underline{F}(2, 60) = 0.7$,

$p > .05$). No significant effects were found in a signal detection analysis, because all participants were performing at optimal levels.

Table 3

BUTTON PRESS LATENCIES DURING A RED SECONDARY TARGET PRESENTATION

Source	Df	MS	F
Total	92		
Between Subjects	30	0.6	
Within Treatments	62	0.002	
Noise Condition	2	0.002	0.7
Error	60	0.002	

CHAPTER V

Discussion

The present study examined the effects of various auditory conditions on a pursuit-tracking task. The results indicated that while time on target decreased during the presentation of red trials, there were no effects on this measure due to the three auditory conditions. This finding suggests that the red secondary target, which required an immediate response, was effective at forcing a shift in attention.

The measure of target boundary crosses was partially independent of the amount of time spent on target due to the possibility of increased numbers of rapid cursor movements while remaining on target. The participant may be rapidly shifting attention between the two opposing tasks. Therefore the total time on target would show no effect, while the number of target crosses would increase.

The results indicated that this is possibly what occurred in the present study, since there was a significant increase in the number of target boundary crosses during red trials when both the "no answer" and the "answer" auditory conditions were present. However, the red secondary target did not effect target boundary crosses during the "quiet" auditory condition. This would indicate that under normal driving conditions, talking on a mobile phone would have no real detrimental effect on driving performance. However, if a distracter is presented, while using a mobile phone, the ability to respond appropriately is significantly impaired.

The resource model may explain these results. Resource demands are surpassed when talking or listening on a mobile phone; causing a lack of resources required to respond to the distracting secondary target. Performance of the primary task, in this case phoning, consumes the required amount of resources and the secondary task (driving) receives only a surplus amount of resources. The remaining resources for the secondary task are not sufficient to maintain a state of alert driving. As noted previously, this reversal of priorities leads to an extremely dangerous situation on the roadways.

The postponement model also could account for the present findings. The phone component would still be considered the primary task. The novelty of the conversation on a mobile phone takes precedence over the automatic task of driving an automobile. According to this model, before a response to a secondary distracter can be processed, the information from the auditory condition has to be processed. Thus explaining the performance decrement under both the "no answer" and "answer" auditory conditions.

A signal detection analysis revealed no effects, probably because all participants were performing at optimal levels. This may have been due to the simplicity of the task. According to the resource model, the amount of resources needed to perform the two tasks would not have surpassed the amount that was available.

The interaction obtained in the present study between the type of auditory condition and the type of task has some important implications for automobile drivers. As mobile phone use increases, our risks on the roadways also increase. Further directions for this line of research should include similar conditions using tasks more closely resembling driving and talking on a mobile phone.

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