The Effect of Cellular Phone Use Upon Driver Attention

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One of the most popular innovations in automotive travel in the past decade has nothing to do with the automobile itself, the people who drive them, or the roads over which they operate. Rather, it is the ability to carry on telephone conversations while driving.

What CB radios were to the '70s, cellular phones were to the '80s. From early 1984, when the first complete systems became operational, the number of cellular phone users has grown to over two million. By the mid-'90s, when cellular service will be available throughout most population centers in the United States, the number of subscribers is expected to grow to between ten and twenty million.

While cellular phones are really elements of communication rather than transportation, their potential impact upon the latter is sizable. The prospect of twenty million drivers having the opportunity to place, receive, or handle a telephone call while driving is not something easily ignored.

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EXECUTIVE SUMMARY

Research has shown that use of cellular phones does not interfere significantly with the ability to control an automobile except among the elderly, where potentially dangerous lane excursions can occur. However, the effect of cellular phones as a possible distraction has not been investigated.

In this study, 151 subjects observed a 25-minute video driving sequence containing 47 situations to which drivers would be expected to respond by manipulation of the vehicle’s controls. Each situation occurred equally often under five conditions of distraction: placing a cellular phone call, carrying on a simple cellular phone conversation, carrying on a complex cellular phone conversation, tuning a radio, and no distraction (i.e., none of the preceding). The radio tuning task was included simply to provide a familiar benchmark. The degree of distraction was measured by comparing responses under each distraction with those occurring in the absence of any distraction. Response was measured in terms of both whether the subject responded and how long it took (with a time penalty for those who did not respond at all).

All of the distractions led to significant increases in both the number of situations to which subjects failed to respond and the time it took to respond to them. Complex phone conversations created the greatest distraction and simple conversations the least, with tuning the radio falling in between. Placing a phone call was no more deleterious than a simple conversation in causing situations to go unnoticed, but delayed responses to about the same degree as did complex calls. Relative increase in chances of a highway-traffic situation going unnoticed ranged from approximately 20% for placing a call in simple conversations to 29% for complex conversations.

The effect of cellular phone use upon response to highway-traffic situations was the most deleterious for the older age group (i.e., 50-80). Overall, the increase in likelihood that some highway-traffic situation will go unnoticed while calling or conversing on a cellular phone was (for the older group) about twice that of their younger counterparts. Older subjects were no more distracted by radio tuning than the middle-age group (26-49 years) and considerably less than the youngest group (17-25 years). As far as time to respond is concerned, age only affected the placing of cellular phone calls.

While a cellular telephone conversation is no more distracting than a conversation of the same intensity with a passenger, the availability of a cellular phone is almost certain to increase significantly the number of conversations in general and the more distracting, intense, business conversation in particular. Older drivers, in particular, should be cautioned against placing calls.

INTRODUCTION

One of the most popular innovations in automotive travel in the past decade has nothing to do with the automobile itself, the people who drive them, or the roads over which they operate. Rather, it is the ability to carry on telephone conversations while driving.

What CB radios were to the ‘70s, cellular phones were to the ‘80s. From early 1984, when the first complete systems became operational, the number of cellular phone users has grown to over two million. By the mid-‘90s, when cellular service will be available throughout most population centers in the United States, the number of subscribers is expected to grow to between ten and twenty million.

While cellular phones are really elements of communication rather than transportation, their potential impact upon the latter is sizable. The prospect of twenty million drivers having the opportunity to place, receive, or handle a telephone call while driving is not something easily ignored.

Cellular Phones and Safety
Thus far, there is no evidence that the use of earphones poses a hazard to the motoring public. What makes the paucity of evidence less than reassuring is the absence of rigorous research in the area. There is the chance of finding out about the involvement of cellular phones in accidents from the reports that are ordinarily prepared by police or drivers. An early study by Brown, Tickner and Simmonds (1969) found that use of the telephone while driving had the effect upon routine driving skills, but did impair the perception of gaps in traffic. At the same time, driving impaired performance on tasks carried on over the telephone. A more recent study by Stein, Parseghian and Allen (1987) studied lane keeping and found significant degradation when placing phone calls in straight driving or on curves with older drivers showing the greater performance degradation. The practical implications of the variation in lane keeping were negligible except for the older age group (over 55), where the likelihood of exceeding the lane edge boundary was over 7%, which the authors translate "to a very high probability of striking an object outside the traveled lane, and thus a high probability of accident involvement." The risk of lane excursions and crashes decreased when the cellular phone was moved from console to dash, although the risk of crash was not eliminated.

The effect of phone use upon the perceptual responses of drivers is likely to constitute a greater threat to safety than its interference with vehicle control. First, perceptual processes play a far greater role in automobile accidents than does vehicle control. "Improper lookout" and "inattention" are the two leading contributors to automobile accidents (Treat et. al. 1977). Second, the extent to which cellular telephone calling interferes with vehicle control can be reduced by dialing aides (e.g., speed dial) and by placing calls only when conditions permit relaxation of vehicle control requirements. The effect of phone use upon perceptual processes, however, is not so readily ameliorated. There is nothing that can be done to the phone to lessen the disruptive effect that mere telephone conversation seems to have on perceptual processes in the Brown et. al. study. Nor can one arrange to schedule telephone conversations around what are primarily unpredictable perceptual tasks. Third, among the population whose driving is most affected by telephone use - older drivers, it is the perceptual processes that undergo the greatest decline. Research has shown significant age-related decrement in general attention, selective attention, attention sharing and spatial judgment.

While Brown, Tickner and Simmonds discovered an effect of telephone use upon perceptual performance, the scope of that performance was limited to judging gaps in traffic. Certainly the criticality of this task to safe driving cannot be questioned. However, other perceptual processes are equally or more critical. The relation of lapses in visual search (lookout and attention) to accidents has already been mentioned.

The interference of telephone calling with the perceptual and cognitive processes involved in driving a car is primarily physical and has to do with the location of the dialing mechanism, the visibility of the keys, and so on. The distraction that results from the carrying on the telephone conversation, on the other hand, is largely mental and is greatly influenced by the nature of the conversation itself particularly, the amount of attention it demands. Casual social conversation is probably no more distracting than talking to a passenger. However, an intense business conversation could well divert a driver's attention to the point that cues of potential danger may be overlooked. A survey of cellular phone users conducted in connection with this study showed that, on the average, 72% of conversations are for business purposes.

Age Related Effects

The attentional processes that must be shared when placing, receiving, or carrying on telephone conversations while driving are known to be vulnerable to age-related effects. The ability to share attention, as between the phone and the road, has demonstrated a relationship to age in studies by Craik (1973), Parkison, Lindholm and Urell, (1980), Temple (1989), and Ranney and Pulling (1990). Deficiencies in the ability to share attention have also been found in drivers over-involved in accidents (Mihal and Barrett 1976, Kahneman 1973). A somewhat less obvious but also relevant variable would be selective attention, the ability to focus selectively upon one set of stimuli in the presence of others. This ability has also been shown to decline with age (Clay 1956, Layton 1975, Rabbitt 1980 and
The studies by Kahneman and by Mihal and Barrett just cited also found declines in selective attention to be associated with over-representation in accidents.

Age has evidenced relationships with a number of psychophysical processes that bear tangentially upon use of cellular phones while driving. Age-related declines have been noted in information processing (Braune et. al. 1985; Welford 1981; Rackoff 1974; and Ranney and Pulling, 1990), problem solving (Case, Hulbert and Beers, 1970; and Arenberg 1982) and short term memory (Miller 1979; Welford 1981; and Temple 1989).

**Purpose of the Study**

The effect of placing and receiving telephone calls upon the ability to control the motion of the vehicle and the interaction of this relationship with age seems sufficiently well-established by Stein, Parseghian, and Allen to obviate the need for further study. The same cannot be said for the effect of telephone use upon the perceptual and cognitive aspects of driving, often referred to as vehicle "guidance", in contrast to the control function. While Brown and Tickner showed that perceptual processes can be degraded by simultaneous telephone conversation, they did not address the full range of cognitive and perceptual functions involved in driving; nor did they examine the important age question.

The purpose of the study described in this report was to assess the effect of telephone use upon the driver's ability to meet the perceptual and cognitive demands of the highway traffic environment. Specifically, it attempted to answer the following research questions:

- What effect do placing calls and carrying on conversations have upon perceptually- and cognitively-mediated responses to highway-traffic situations?
- How do these effects relate to the complexity of the conversation?
- How do these effects vary across highway traffic situations?
- How do any of these effects vary with age?

**METHODS**

The effects of cellular phone usage upon the ability of drivers to cope with the perceptual and cognitive demands of driving was studied by confronting samples of drivers with highway and traffic conditions calling for certain vehicle control responses and comparing the responses occurring under ordinary driving to the responses when drivers are handling telephone conversations.

**General Approach**

Any attempt to study the effect of cellular phone use upon driver cognitive and perceptual processes is challenged by the varied and unexpected nature of the demands that are placed upon these processes. A truly empirical assessment of the cellular phone's effects requires a measure of the driver's ability to meet various perceptual-cognitive demands with and without concurrent use of the phone. Such comparisons can be made without great difficulty when the demands upon the driver come from fixed characteristics of the highway environment, such as intersections or signs along the highway. But, much of what drivers have to respond to involves the actions of other road users - a driver who may pull out from a side road, or a child who might enter the street.

In actual driving, the actions of individual road users are one-time events and therefore do not lend themselves to comparisons. While they can and have been deliberately staged for research purposes (McPherson, McKnight, and Wiedman, 1983), the cost of doing so severely limits the number of events that can be presented to the subjects and the number of subjects who can be exposed to the events. Therefore, in situ studies are suitable for registering only those salient influences that can be counted on to manifest their effects in small sample studies. The effects of phone conversations upon driving,
on the other hand, are likely to be very subjective. Yet, because of the vast opportunity for such
distractions to occur, and because of the enormous opportunity for injury to arise, the effects can
have serious consequences.

**Types of Distraction**

The independent variable under study was distraction. In this discussion, the term "distraction" refers
to a diversion of attention from driving produced by some situation. The situation of primary concern
is, of course, use of a cellular telephone. The car phone itself involves minimum distraction. The only
time a driver is distracted by the apparatus is during the act of placing a call. Even when the dialing
pad is placed on the dashboard and cut close to the line of sight, attention must be diverted from the
path ahead. There is evidence that when people focus their attention upon one stimulus, they may fail
to perceive another stimulus separated from the first by but a few degrees of visual angle. To assess
the effect of placing a call upon driver attention, subjects were required (at various points of the test
procedure) to dial a number given them orally by the experimenter.

The conversations taking place on the telephone are also a possible distraction. As we pointed out in
the Introduction, what distinguishes cellular phones from in-person conversations is the higher
instance of calls carried on for business rather than social reasons. It seems likely that calls involving
business would be somewhat more attention demanding than purely social conversations. To allow
differences in the intensity of conversation to evidence any effects upon degree of distraction,
conversation took place at two levels, casual conversation, in which subjects talked with the
experimenter about a variety of largely inconsequential topics, and intense conversation in which the
subjects engaged in a set of problem-solving exercises. Testing distraction at two levels of
conversation does not assume that the intense cellular phone conversations are truly more intense
than conversations with passengers -only that level of intensity is a variable that warrants study.

A distraction with which operation of any in-vehicle equipment is often compared is that of tuning a
radio. The comparison is typically invited by someone defending introduction of a particular piece of
equipment and using radio tuning as a lawyer might use a legal precedent. It has been used so often
as to become something of a benchmark in studying in-car distraction. For this reason, it was included
among the "distractions" with which telephone conversations were compared.

To gauge the effect of various acts in distracting attention, we need to be able to compare them with a
condition that offers no distraction, that is, simply driving the car. The people in this situation might
find things to occupy their attention other than driving, they would be at least free of any planned
distraction.

To summarize, the five conditions creating different types and degrees of distraction were as follows:

- **No Distraction** - The absence of any planned distraction
- **Placing a Call** - Dialing a telephone number on a key pad located close to the driver's line of
  sight
- **Casual Conversation** - Social chit-chat between subject and experimenter
- **Intense Conversation** - Subjects solving problems presented orally by the experimenter
- **Tuning a Radio** - Adjusting a car radio to pre-determined station

**Dependent Variable**
The effect of cellular phone use under study was the degree of distraction from primary driving tasks. Distraction itself is not directly observable. It is a hypothetical construct that explains why performance of some task is degraded in the presence of certain conditions. The performance degradation becomes the measure of distraction.

The performance of concern in the present study was the driver's perception of those elements of the highway-traffic environment that require the driver to do something. Of primary concern are those situations in which the driver must do something to prevent an accident. A somewhat lesser concern to society (but important to the driver) are those responses that enable drivers to get where they are going. In this study, both were valuable as indicators of perception and therefore any distracting effect of cellular phone use.

The extent to which cellular phones become a distraction can be assessed through measures of response to changes in the highway-traffic environment that require the driver to do something; such as a car ahead slowing down or a pedestrian about to step into the street. The presence of a distraction could be inferred from failure to respond when one would otherwise do so, or from taking longer to respond. Of course, we could simply ask drivers if they actually saw whatever it is they were supposed to respond to. However, in this study, such a response would alert subjects to what we were looking for and quite possibly change the very behavior we were trying to measure. Therefore, distraction was measured by comparing vehicle control responses of drivers to simulated highway-traffic safety scenes.

The scenes that were presented to drivers in the study all involved situations to which they would normally be expected to respond by some adjustment to the speed and/or direction of the vehicle. One category of such situations would be normal responses to changes in the route, such as turning a corner at an intersection in order to follow a predetermined route. Another would involve responses to traffic controls, such as, traffic lights or stop signs. Situations presenting possible danger, when perceived, should lead to some reduction in speed. Where the probability of actual danger is relatively small, or the distance to it is relatively large, the normal reaction is simply to take the foot off the accelerator until the danger becomes imminent. Where the danger is close at hand, and speed reduction more urgent, the appropriate response is brake application or, in some cases, steering the vehicle away from danger. If the use of cellular telephones is having a distracting effect, the distraction should be apparent in a difference between vehicle control responses when the potentially distracting influence of the telephone is present versus the response which occurs in the absence of any distraction.

The measure of distraction was the difference between responses occurring when no distracting condition was present and those that occurred under the four distraction conditions making up the independent variable. Two response measures were employed:

- **Response Occurrence** - Whether or not the driver responded
- **Response Time** - How long it took the driver to respond

These two measures made up the dependent variable under study. The distraction attributable to any one of the potential Distractors was a function of the difference between that condition and the no-distraction condition relative to response occurrence and response time.

**Study Parameters**

Of the many variables that might influence the distraction resulting from cellular phone use the one of most concern was age. Of course age, as the mere passage of time, would not be expected to influence anything. However, age has demonstrated a relationship to deficiencies in a number of mental functions likely to affect distraction including information processing, attention sharing, selective attention, useful field of view, and memory. To allow the relationship between age and distraction to be examined, subjects for the study were recruited from a wide range of age levels; with
quotas established such as to assure sufficient numbers of older drivers to permit any difficulties associated with advanced years to reveal themselves.

Another variable we might expect to influence the effect of cellular phones upon any aspect of driving would be experience in their use. Practice in placing calls could lead to dialing without having to look, while conversing at length could lead to greater facility in attention sharing. To permit distraction to be analyzed in terms of experience, an effort was also made to recruit substantial numbers of cellular phone users for the study.

**Study Sample**

To study the relationship between cellular phone use and the driver's ability to respond to the demands of the highway traffic environment, we needed a sample that was generally representative of the driving population at large with respect to those relationships. Samples of subjects can be quite different from the at-large population with respect to many variables, including the variables under study, and still be reasonably representative with respect to relationships among variables. The only requirements for entry into the subject pool were experience in driving and the absence of any known problems that would have adversely affected their response to highway hazards.

A total sample of 150 was believed necessary to provide a reliable outcome. To assure that the age distribution was not severely biased in one direction or another, one-third of the sample was to come from each of the following age groups: Young (25 and under), mid-range (26-49), and older (50 and older). Since ages were not known until the subjects arrived, the division could only be approximated. The final sample included 45 young, 57 mid-aged, and 49 older, for a total of 151 subjects. The mean age of the sample was 39 years, corresponding exactly to that reported for cellular phone users by Sextro (1989). In order to permit experience to be studied as a variable, we established a quota of 50 cellular phone users, a quota that was met.

Subjects for the study were recruited primarily through posters placed in neighborhood stores and offices. The announcement offered a payment of $20 for one half-hour's participation in a study involving operation of an automobile simulator. Since older drivers and cellular phone users were likely to be underrepresented in the population reached by the announcement, additional efforts were made to recruit subjects from these sources. A route to older drivers was offered by the American Association for Retired Persons "55 Alive" Driver Improvement Program at which we made in-person solicitations. To attract cellular phone users, we placed flyers under the windshields of parked vehicles sporting cellular phone antennas.

**Test Procedure**

To study the possible distractive effect of cellular phones, subjects observed a series of videotaped driving scenes to which they responded by manipulating a set of simulated vehicle controls. The conditions under which the activity took place were varied systematically across the five conditions of distraction mentioned earlier (none, placing a call, tuning a radio, simple conversation, and intense conversation).

**Simulation**

The only practical means of presenting large numbers of drivers with the same array of traffic conditions is through simulation. Stein, Parseghian, and Allen employed simulation to measure the effects of phone use upon lane keeping. Because lane keeping requires continuous interaction between what drivers see and what they do, the simulator was of the interactive variety.

At the present time, interactive simulators are severely limited in the complexity that their displays provide. The most sophisticated type of interactive simulator, and about the only type currently in use, generates images by means of a computer. Since each image must be individually programmed, the
amount of programming rises sharply with the number of images. The static aspects of the highway environment—road delineations, highway structures, traffic controls—are obviously easier to handle than are cars, pedestrians, and other road users, who not only must be programmed to move but must move in a way that responds to the acts of the driver. Highways filled with oncoming, overtaking, and intersecting traffic, and sidewalks teaming with pedestrians, are simply beyond the computer power or programming capabilities of present-day art—at least within the realm of what is affordable. Yet, if use of cellular phones affects cognitive and perceptual processes, the effects are most likely to manifest themselves under conditions of high stimulus complexity. Even distracted drivers are not likely to overlook a pedestrian entering the street when it is the only thing moving for miles around.

Simulating the complexities of the highway traffic environment with any fidelity at all requires the use of cameras rather than computers. In this study, we videotaped a series of scenes through the windshield of a moving automobile to create the driving tasks to which subjects of the study would respond. Each 30 seconds of video tape contained at least one highway or traffic condition requiring a driver control response to change vehicle speed or direction.

When played back to subjects, each highway-traffic condition was made to coincide with a task involving some degree of possible distraction from use of cellular phones, including no distraction, making a cellular phone call, engaging in a casual phone conversation and engaging in an intense phone conversation. The effect of the cellular phone could then be assessed by comparing responses to the highway, traffic conditions which arose during calling or conversing on the phone with responses to conditions that arose when no distractions occurred. A radio tuning task was included as a reference aide, to allow any distraction associated with cellular phones to be compared with a form of distraction that is generally familiar. The effect of the distraction upon the driver’s perceptual and cognitive functioning would be assessed by studying whether and how quickly people respond to various highway traffic conditions. The greater the distraction from a cellular phone, the less likely the subject would be to respond or the longer it would take for response to be initiated.

**Driving Scenes**

The scenes presented to subjects involved some 47 situations to which drivers might ordinarily be expected to respond. The situations included the following:

- **Vehicles** - Stopping, turning, entering, crossing, etc. (18)
- **Road Configuration** - Lane drop, lane control, narrow bridge, etc. (10)
- **Pedestrians or Animals** - (4)
- **Route Change** - (4)
- **Road Sight Limitations** - (3)
- **Roadside Construction** - (3)
- **Traffic Control Signal** - (3)
- **Road Surface Conditions** - (2)

A Betacam video camera was mounted in the rear seat area of a Mazda 626 at about the height of a short driver. The camera was approximately equidistant between the left and right sides of the car. A rear-view mirror was placed in the camera’s field of view providing a view of the area to the rear of the car corresponding to the view normally seen in a driver’s rear-view mirror with the exception that this mirror also reflected a very small portion of the camera itself. The presence of the camera, however, had the affect on the ability to see and understand what was happening to the rear. All routes were identified in advance of the day of shooting as well as the location and nature of certain pre-planned conditions to occur along that route. In addition to pre-planned situations there were many naturally-occurring events that were recorded along the routes. Indeed, most of the situations appearing in the video involved characteristics of the route or traffic situations that just happened to arise during the videotaping.
The four route changes were brought about by superimposition of an arrow in the upper-right corner of the video image. The arrow pointed upward, indicating no direction change, except at the four points along the route where a turn was to be made; that is, where a turn occurred in the video image. Originally, we had intended to plant route sign facsimiles along the side of the road as a means of guiding subjects. However, many of the subjects were familiar with the stretches of road employed in the test, and were aware that no such routes existed. Superimposing an arrow upon the image allowed us to test the subject's ability to perceive route changes without requiring them to remember or respond to a designated route.

A 3/4" copy of the Betacam master was played back from 3/4"deck into a 50" screen rear-projection television. Footage was viewed to identify sections containing a variety of hazards which occurred frequently and at timely intervals. The "best" sections were edited and spliced together to create a program that ran approximately 25 minutes. This program was then screened to identify all highway-traffic conditions that could be used to test reactions. A pilot group of available & "subjects" drove the simulator along with the video. The situations that drew reactions from one or more of the subjects were noted. This information was used to determine which situations were worthwhile for use in the video. A situation was eliminated where two situations occurred too closely to one another. This did not allow sufficient time for the termination of one distraction after the first situation and the beginning of a new distraction before the next situation began. This culling process resulted in a list of 47 evenly-spaced situations to which subjects could be reasonably expected to react.

Response Recording

The perceptual responses to the highway-traffic environment that might be affected by cellular phones are observable only by those doing the perceiving. Distraction was therefore measured through observation of a subject's physical response to the various situations pictured in the video scenes that were presented to them. As a subject "drove along" with the video scene, a video camera and VCR recorded the subject's:

- Accelerator use, by means of a voltage meter connected to a potentiometer that was, in turn, connected to the accelerator pedal
- Braking, by means of a light that was connected to a brake light switch
- Steering and turn signal use which were visible to the camera

The accelerator meter and brake light were mounted behind the camera and reflected into the camera's view with a mirror mounted in front of the camera.

Cellular Phone Tasks

The three telephoning tasks, and the "benchmark" radio tuning task were controlled by the test administrator in the following manner:

Radio Tuning -To initiate the radio tuning task the administrator would press a button that turned on a radio next to the subject. This would be the cue to the subject to turn on the simulator radio and to try to match the test administrator's station. The radio was left on until the situation section was over. In the event that there was sufficient time between the end of one situation and the next, the radio would be left on a while longer to give the subject as much time as possible to find the correct station. We felt that subjects who were successful in finding the station would be less likely to become discouraged and would therefore take the task more seriously.

Call Placing -To initiate a call-placing task the administrator would press a button that lit a light just under the TV screen. This was the cue to the subject to place a call to his or her home phone number. If it was necessary to extend the length of the call-placing task to make it last
through a longer situation section, the subject would be told that the line was busy, which was a cue to call a second number, such as his or her work number.

Simple Conversations-These generally involved discussions on subjects including, but not limited to, the gathering of demographic information (age, car phone experience, familiarity with the route, etc.), what the subject did for a living, what the subject did with his or her free time (e.g., what they did during the previous weekend or what they might be doing after work that evening). It was not generally difficult to keep an active conversation going throughout the situation section and terminate it quickly at the end of the situation section.

Complex Conversations-These consisted of either math problems or short-term memory problems. The math problems consisted of a string of simple computations (e.g., $2 + 3 + 4 + \frac{1}{2} x 3 + 4 + 6$). Each computation was simple enough that subjects with limited math abilities could reasonably be expected to perform them. However, since subjects were required to keep a running total in their heads, they needed to maintain attention for the duration of the problem to get a correct answer. In the short-term memory task subjects were read a list of five or six digits and were then asked whether certain digits were in that list.

Simple and complex conversations were generally preceded by a call-placing task which acted as a natural lead-in to a conversation. Since it takes longer to get into and out of conversations, these distractions were generally programmed to stretch over two situation sections.

There was nothing administrators had to do to initiate a no-distraction situation except to assure that the previous distraction was terminated by the time the no-distraction section began.

Test Forms

The individual subjects could not be exposed to every highway traffic situation under all five distractions without being exposed to the same situation five times, an undesirable state of affairs. In order to limit subjects to a single exposure, the distracting conditions were introduced in five different sequences such that each sequence matched a particular highway traffic situation with a different distracting condition. The different sequences or "forms" were rotated among subjects in such a way that each form was given equally often. This meant that, across the entire sample, each distraction condition was paired equally often with each highway traffic situation.

Administrative Procedure

The test was administered from a room, separated from the simulator by a twenty foot hallway and a closed door. The test administrator's main function was to control the presence and type of distractors. The administrator observed the simulator video via one video monitor and the data collection video via a second monitor. This made it possible to view what the subject was watching on the simulator which, in turn, facilitated the timing of distractors to the appropriate hazards. Monitoring the data collection video made it possible to assure that the camera was capturing the necessary information, the assorted meters and lights were functioning properly, and that the subject was "driving" in a realistic manner. The test administrator also monitored the beginning and end of the hazard sections via speaker from the audio track of the 3/4" deck and addressed the test subject via microphone to a commercial stereo tuner/amplifier which was connected to a speaker in the testing room. An audio signal on the simulator video tape that identified the beginning and end of each hazard section was sent to the test administrator to help the administrator control which distraction was in place during each hazard. This audio program was also sent to an audio mixer that mixed it with a microphone in the simulator room and sent it to the data video recorder. This made it possible for the person reducing the data to time reactions from the same point for each hazard, for every subject.
A noise gate was connected between the microphone and the amplifier to turn the microphone off automatically when administrator was not speaking. This was necessary to prevent the subject from hearing the radio station being tuned prior to tuning tasks and hazard section cues being sent into the administration room.

The test administrator had an instruction sheet for each subject which served as a guide to which distractions should be given during each highway-traffic situation.

Data Reduction

All data reduction was performed from the data video tape, that is, the video of the subject's performance. Data reducers used a stopwatch to time the reactions to the hazards and noted cases where the subject did not react at all. Performance in the distracting tasks was also recorded. Subjects were scored high on distraction tasks for:

- Completing calls quickly
- Searching for radio stations continuously, with no apparent need to stop tuning to deal with the hazard
- Engaging in simple conversations continuously, with no apparent need to stop talking to deal with the hazard
- Correctly solving math problems and correctly identifying numbers that were or were not included in the list of numbers given in the short-term memory task

Data Analysis

The analysis involved comparing different forms of cellular phone use and radio tuning with respect to the degree of distraction in responding to various highway traffic situations. A measure of distraction was obtained by subtracting an individual subject's "scores" (response time and proportion of situations responded to) under no distraction from the scores under each distracting condition. The difference between the two scores became the measure of distraction. These scores were then aggregated across subjects, separately for response time and proportion not responded to.

The analysis employed was a factorial Analysis of Variance, in which the independent variable - the four potential distractors - formed the factor of primary interest. Two other factors included in the analysis were age and form. The importance of age as a parameter was discussed earlier. For any analytic purposes, subjects were divided into the three age groups noted previously: 25 and under, 26-49, 50 and over. The oldest age group actually ran up to age 80, with a median age of 61 years.

Test "form" was isolated as a factor for purely statistical reasons; since the test forms are entirely arbitrary, their relation to any of the variables in question was not an item of interest. While each test form consisted of the same high way-traffic situations, the way the situations interacted with the various distracting conditions was such that forms might differ somewhat with respect to the two dependent variables. Since it was not possible to balance the test forms across the different age groups, failure to control for the effects of test form could end up introducing a relationship between distractor and age that was truly an artifact. Treating the test form as a factor prevented any differences in forms from effecting the other comparisons.

RESULTS

- Effects of Distractions
- Effects Of Age
- Effects Of Experience
- Relative Performance Decrements
Effects of Distractions

Figure 3 displays, for each of the four potential distractors, the level of distraction with respect to response time and whether or not subjects responded. The two distraction variables displayed in the figure are not independent of one another; where subjects failed to respond to a situation, the maximum response time taken by any subject exposed to that particular situation under that distraction was entered as the response time. Had this not been done, the non-responders would not have appeared in the response time data and the results would have been meaningless.

FIGURE 3 INCREASE IN REACTION TIME AND NON-RESPONSES BY DISTRACTION TYPE

Click here for Figure 3

All of the potentially distracting conditions yielded some degree of distraction, that is, they produced reaction times and non-responses that were different from the no distraction condition. The overall level of distraction was highly significant for both non-responses ($F = 36.07; DF = 1,136; P<.01$) and for response time ($F = 286.75; DF = 1,136; P<.01$) and under all four potential distractors ($P = <.01$). Overall, the various distractions increased the length of time needed to respond to highway traffic conditions by from .4 to .9 seconds, and the proportion of situations missed entirely from .06 to .09.

When it comes to which condition led to the greatest distraction, the results varied somewhat from one of the two distraction variables to the other. Looking at the proportion of subjects who were distracted from responding at all, the complex conversations yielded the greatest interference, while placing calls and carrying on simple calls yielded the least interference and tuning the radio fell somewhere in between. The differences among all distractors were only marginally significant ($F=2.133;DF=3,134;P=.10$). However, complex conversations were significantly more distracting than simple conversations ($F = 4.12, DF = 1, 134; P =.04$).

Turning to the time it took to respond, we see that placing a telephone call rose from one of the least distracting to one of the most distracting conditions. The differences across distractions are statistically significant ($F=4.37;DF=3,134 ;P<.10$). Considering that those who failed to respond are included within the response times, it is clear that it is the delay in responding among those who actually responded that account for the difference in outcomes. What the results seem to say is that the act of placing a cellular phone call may be no more distracting than carrying on a casual conversation in so far as noticing highway traffic conditions is a concern. However, it does seem to extend somewhat the delay in responding. When a non-urgent situation arose while a call was being placed, many subjects delayed responding until they had completed the call. But they did respond, indicating that the situation had not gone unnoticed.

Effects Of Age

FIGURE 4 INCREASE IN REACTION BY AGE AND DISTRACTION TYPE

Click here for Figure 4

Figure 4 displays the proportion of drivers failing to respond to highway traffic conditions as subdivided by age. It is evident that drivers in the over-50 category show strikingly higher proportions of failing to respond to highway traffic situations. The overall effect across distraction conditions is not
statistically significant (F = 2.22; DF = 2,136; P = .13). However, the deficiencies of older drivers significantly exceed those of the other two age groups in telephone calling (F = 7.96; DF = 1, 141; P < .01), and simple phone calls (F = 5.13; DF = 1, 141; P < .05), but not complex phone calls (F = 2.34; DF = 1, 141; P = .13). Also, in tuning the radio, age differences were not statistically significant (F = .73; DF = 1,141; P = .39).

Part of the explanation for the failure of the radio tuning task to show significant age effects is the relatively high degree of distraction evidenced by the 17-25 year age group. The results suggest that this age group is somewhat more preoccupied with tuning the radio than with telephone calls, a hypothesis that most parents having children in this age group would have little difficulty accepting. But why significant age differences didn’t appear in complex calls lacks a ready explanation. It may be that complex conversations are more or less equally distracting to everyone, while placing calls and carrying on simple conversations only distracts the older subjects. Perhaps a more parsimonious explanation is that age amplifies the effects of all telephone-related distractions and that the differences among the three types of distractions are largely the result of chance.

Turning from whether drivers respond to how long it takes them to do so, Figure 5 shows the effects of age to be somewhat attenuated. Over all distraction conditions, the effects of age are statistically non-significant (F = 1.14; DF = 2,136; P = < ;.32). The only two conditions showing a marked increase in reaction time for the older age group are placing telephone calls and carrying on simple conversations, of which only placing calls achieves significance (F = 3.01; DF = 2,136; P = .05). The effect of phone use upon older drivers seems more to prevent them from noticing various highway traffic conditions rather than to retard their response to them.

**FIGURE 5 INCREASE IN RESPONSE TIME BY AGE AND SITUATION TYPE**

[Click here for Figure 5]

**Effects Of Experience**

Prior experience with cellular phones appeared to have no significant effect upon distraction resulting from phone use or tuning the radio. Across all distractions, differences between experienced and inexperienced subjects were statistically non-significant for response time (F=1.55; DF=4,114; P=<.19), or for the likelihood of responding at all (F=0.39; DF=4,114;P=<.81). What slight differences occurred seemed to favor the inexperienced, although such differences, if they exist, can be attributed to the fact that the experienced subjects tended to respond more quickly when there was no distraction and might therefore tend to evidence a slightly greater difference between the undistracted and distracted conditions. In looking simply at raw reaction times under the various distractions, the experienced subjects responded as quickly or more quickly than the inexperienced subjects. In any case, it is clear that prior experience with cellular phones has no real impact upon the degree to which one is distracted by its use.

**Relative Performance Decrement**

The decrements in performance that have been discussed amount to greater response time and the probability of not responding as compared with the results obtained in the absence of any distracting condition. Just how bad these decrements are can only be understood in relation to just how slow or unlikely to respond people are in the absence of any distraction. For comparison purposes, it is necessary to know that the mean response time in the absence of any distraction (across all highway traffic conditions) was 4.45 seconds, across all situations, while the proportion not responding at all was .343, again across all situations.

Considering the proportion of subjects not responding, the relative decrements experienced by the older age group in placing calls was (.127/.343 = ) 37%, simple telephone conversations (.108/.343 =) 31%, and complex phone conversation (.123/.343 =) 36%. For the other two age groups,
performance decrements were much smaller, the largest being a (.072/.343 = ) 21 % greater probability of not responding for the 17-25 year age group when making complex phone calls.

The condition leading to marked increases in response time was where the oldest age group had an increase of 1.417 seconds in placing calls. Expressed as a percent of the response lag under no distractions, this translates to increase in response time of 32%. Decrements in the remaining cases were considerably smaller, falling largely between .4 seconds (9%) and .8 seconds (18%).

**Specific Situations and Distractions**

The effect of using the telephone or tuning the radio upon response to highway traffic situations was not uniform across all situations. Interaction between the effects of distractions and various highway traffic situations was evident as a highly significant difference across the five "forms" i.e., the ten combinations of distractions and conditions occurring in the video. Recall that five different forms were needed to allow each of the five phone conditions to be matched with each of the highway traffic conditions without exposing the same subject to the test route more than once. Since the forms do not differ with respect to either distractors or highway traffic situations but only in the way they were combined, the significant differences among forms means that certain combinations of the two variables were particularly problematic.

To see if there was any pattern to these aberrant combinations of potential distractors with highway traffic conditions, they were examined individually. Specifically, those combinations leading to proportion of non-response that were discrepant from what would be expected from the effects of the distractors or highway traffic conditions alone were identified through a logit analysis.

The results were not at all revealing. The number and nature of aberrant combinations followed a chance pattern. As to the number, only four of 235 combinations fell beyond a .05 confidence interval around the expected results, whereas one would have expected (235 x .05 =) almost 12 by chance alone. As to the nature, no logical pattern could be discerned in the results. It should be noted, that with 150 subjects and five conditions, each condition was only replicated 30 times for a particular highway traffic situation.

**Performance on Distractors**

Thus far, our concern for the effect of various potential distractors upon response to highway-traffic situations has been limited to whether or not simply engaging in the task influenced driving performance. The distracting effect of cellular phone use or radio tuning tasks upon the response to highway-traffic conditions might be expected to vary as a function of the amount of attention devoted to the tasks. A measure of the amount of attention paid to the distracting tasks would be performance on those tasks themselves. This aspect of performance was assessed as follows:

- **Radio Tuning** - Whether the tuning process was continuous or whether it was interrupted by the associated highway-traffic situation
- **Placing Calls** - Length of time required to complete placing the call
- **Simple Conversation** - Any interruptions in the conversation coincident with appearance of a highway traffic situation
- **Complex Conversation** - Incorrect answers to the problems being solved
Time to complete the radio tuning task could not be used as a criterion since it was largely determined by how much the dial had to be manipulated to reach the target station, something that varied by chance from one trial to another.

If differences in quality of performance on the distracting tasks influenced responsiveness to highway traffic conditions, chance differences in quality of performance could obscure relationships under study unless a it was used as a covariate when analyzing those relationships. However, when quality of performance on the distracting task was compared to amount of measured distraction, no significant relationships materialized. For example, whether or not subjects answered to problem solving questions correctly during complex conversation was unrelated to the distraction the problem solving caused itself.

**DISCUSSION**

The three tasks associated with use of cellular phones - placing calls, simple conversations, and complex conversations - all led to significant increases in time to respond to highway traffic conditions and in the likelihood in failure to respond at all. As might be expected, complex conversations involving problem solving led to the greater degree of performance decrement - about on par with tuning a radio. The act of placing cellular phone calls yielded increases in response time similar to that of complex conversations, but increases in non-response that were similar to simple conversations.

The overall results conceal large age differences. The proportion of drivers age 50 and over failing to respond to highway traffic conditions while using cellular phones was two to three times greater than that of younger subjects. Among those responding, the oldest subjects took significantly longer to respond than their younger counterparts when placing calls, but evidenced no slower response time than the two other age groups when conversing on the phone. Tuning the radio, while a highly distracting task, appeared equally so for all age groups. Prior experience with cellular phones appeared unrelated to the degree of distraction involved in using cellular phones.

**Magnitude of Problem**

How concerned should we be with the distraction created by use of cellular phones? Of the two dependent variables, non-response and response time, the former is certainly the more important. First, whether or not drivers notice and respond to elements of their highway-traffic environment is certainly more important than how long it takes them to do so. We are not dealing with emergencies, where time is of the essence. The situations to which subjects were expected to respond became evident almost five seconds before the average subject felt it was necessary to do anything. The decrements of less than a second that result from use of cellular phones represent a relatively small increment in total response time. Second, the response time measure employed in the present study was somewhat artificial, including what amounted to a penalty for failing to respond.

For the driving population at large, simple casual conversation seems to have little impact upon the ability of people to notice and respond to the demands of the highway and its other users. Nor does the act of placing calls seem to divert attention, although drivers may take some fraction of a second longer on the average to respond. It is those conversations that require intense concentration on the part of the driver that appear to be most distracting. When confronted by those highway-traffic situations presented in this study, their chances of not responding increase by almost .10, which is approximately a 30% increase over the non-response rate when no distractor is present. An increase of this magnitude and the chances of not noticing something, while small, is nonetheless cause for concern. Someone might point out that the performance decrement it represents is no worse than that which occurs when tuning a radio. However, the amount of time during driving that is devoted to tuning a radio may be considerably less than the time spent in intense phone conversation by those who use cellular phones for business purposes.
The greatest deficit in ability to respond to highway-traffic situations is experienced by the older drivers. The frequency of non-response was from almost two times to over three times that evidenced by their younger counterparts. The degree of deficit was rather similar across the three phone tasks (calling, simple, and complex conversation), increasing the likelihood of non-response by 1.11-1.13, representing a 33-38% increase over non-responses in the absence of any distraction. Among the older drivers, the distraction resulting from the use of cellular phones was again half as large as that involved in tuning a radio, which was actually the most distracting for the youngest age groups.

One legitimate question might be to what extent the distractions from casual and complex conversations are truly a cellular phone problem. While placing a call is a phone-specific task, the carrying on of conversations is not. Under the “hands off type of cellular phone simulated in the present study, conversations were really no different from those that might be carried on with another passenger. But, what a cellular phone can do is bring into the vehicle conversations that are more frequent and more likely to be intense than those that would occur with passengers. From accident statistics we know that drivers are unaccompanied about two-thirds of the time. It seems very likely that introduction of a cellular phone brings about a significant increase in the likelihood of intense phone conversations.

Implications

The results of the study that has been described carry two significant implications for use of cellular phones. First, all users of cellular phones should be advised not to engage in intense phone conversations while the vehicle is moving. Businesses whose employees regularly carry on transactions by means of cellular phones might advise, or even direct that protracted dealings over the phone be avoided while the vehicle is underway.

The second implication has to do with older drivers. Not only is the performance deficit of drivers over 50 years of age significantly greater than that of younger drivers, but it prevails over all three of the cellular phone tasks studied. If there is any group that should not be using cellular phones while driving, it is those in the older age group. Gerontological research in general shows that the severe deterioration in mental processes tends to become more and more prevalent beyond age 70. One might therefore expect markedly greater instances of failure to respond to highway-traffic situations at these advanced years. Unfortunately, the number of test subjects in this age category was not sufficient to permit this possibility to be tested.

There is no reason to discourage older drivers from having cellular phones in their vehicles. Phones provide them with a very valuable way of summoning help in the event of illness or mechanical breakdown without advertising their plight over a CB radio. However, the diversion of attention, coupled with the difficulties in vehicle control found by Stein, Parseghin and Allen (1987) contraindicates their use while the vehicle is in motion.

Conclusions

From the results of the study that has been described in this report, the following conclusions may be offered.

1. All forms of cellular phone usage lead to significant increases in the establishment of non-response to highway-traffic situations and increase in time to respond.

2. Complex, intense conversation leads to the greatest increases in likelihood of overlooking significant highway traffic conditions, and the time to respond to them. The distracting effect is similar to that of tuning a radio. The effect of placing calls or engaging in casual conversation is less of a problem, although, calling tends to retard responses.
3. The distracting effect of cellular phone use among drivers over age 50 is two- to three-
times as great as that of younger drivers and encompasses all three aspects of cellular phone
use - placing calls and carrying on simple and complex conversations. The effect is to increase
non-response by 33-38%.

4. Prior experience with cellular phones appears to bear no relation to the distracting effect of
cellular phone use.

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