Testing Driver Cognitive Distraction

Caused by Cell Phone Use

Design Proposal

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1.0 INTRODUCTION

Research has shown that the distraction caused by operating a cell phone may take away from the driver's ability to operate the vehicle. In 1998, the National Highway Traffic Safety Administration (NHTSA) reported that 7.2 per cent of accidents were caused by distracted drivers; cell phone usage accounts for a significant fraction of these cases[1]. The exponentially increasing number of portable phones makes cell phone caused accidents a growing concern. The Center for Urban Transportation Research (CUTR) reported that the number of cell phones used in motor vehicles increased from 500,000 to more than 63 million between 1985 and 1999 [2]. Spurred by these statistics, many countries are looking at the possibility of passing laws designed to make cell phone usage safer, or even to prohibit phone use while driving. Currently only the states of California, Florida, and Massachusetts impose restrictions on the use of cell phones and these restrictions are minor[3]. However, at least 27 states are currently considering passing cell phone legislation, and numerous local jurisdictions have moved forward in passing bills[1,3]. Further research is needed to understand how and why cell phones impact driving ability, and how these effects can be counteracted.

Most studies about driving and cell phone usage have focused on the physical distractions: "head down" time while picking up the phone, dialing, and answering a call, and monopolization of the driver's hands while s/he operates the phone. The proposed solution to these physical distractions is the use of hands free devices in cars. However, fewer studies have looked at the cognitive distraction caused by cell phone conversations and their impact on driving ability. Some theories argue that since driving is primarily a vision-intensive activity, and cell phone usage is primarily a hearing-intensive activity, the two tasks require different sensory channels and should not interfere with each other[4]. Yet as more research accumulates, it is becoming increasingly apparent that the cognitive distraction caused by cell phones has a detrimental effect on driving ability[4,5]. This result must be further studied to devise effective countermeasures, and to make informed decisions about legislation that will decrease accidents caused by cell phones.

2.0 OBJECTIVE

The primary objective of this project is to investigate the effect of cognitive loading caused by a cell phone conversation – the amount of cognitive processing required to understand the conversation and respond – on the response time and situational awareness of the driver, and consequently attempt to recommend approaches to counteract the cognitive distraction. As a secondary objective, two age groups, consisting of young (18-25 years of age) and older (above 60 years of age) subjects, will be tested to look for possible changes in the effect of cell phones with changes in age. The test subjects will be tested in the driving simulator at the MIT Age Lab. They will be presented with a driving scenario in which driving ability will be tested through response time and situational awareness. The test subjects will be tested in three phone set-ups – no phone, hands free cell phone, and hand held cell phone, and four cognitive loading levels – none, low, medium, and high. The data will be analyzed for changes in response time and situational awareness with changing phone set-up and cognitive loading. If possible, recommendations will be made on how to decrease the distraction caused by cell phones.

3.0 PREVIOUS WORK

Previous work has focused on the physical distraction caused by cell phones, and its effect on driving. The results have shown that the physical distraction does increase response time[1]; "head down" time may cause the most significant contribution to this increase in reaction time. Studies into the cognitive distraction caused by cell phones show that the conversation is also an important factor in decreasing driving ability. Some studies suggest that cognitive distraction may even be a more significant distraction compared to physical distractions caused by hand held cell phones[4,6].

A study at Miami University found that reaction time for braking was 24 per cent slower when test subjects were talking on a cell phone[7]. However, changing the difficulty of the conversation appeared to have an insignificant impact on response time. The testing required the test subject to move her/his foot from a simulated accelerator to a simulated stop pedal when a red light was shown; the testing was conducted while the subject was under cognitive loading. The cognitive loading was imposed by listening to a weather forecast, answering simple questions, answering complex questions, and talking about topics that may induce an emotional response.

A study at the University of Toronto looked at the cell phone usage of 699 drivers who were in a car collision[6]. The results were obtained by studying the drivers' cell phone call records. It was determined that the risk of collision increased four times when a cell phone was being used. Perhaps the most interesting result was that the use of a hands free cell phone did not seem to reduce the risk of an accident, compared to a hand held phone. As well, the risk was similar for drivers of various age groups and driving experience.

At the University of Utah, researchers showed that drivers were twice as likely to miss a traffic signal when they were deeply involved in a cell phone conversation[4]. No difference was found between using a hands free compared to a hand held cell phone. The experiment involved 32 female and 32 male subjects, who were required to follow a moving point on a screen using a joystick. While the results showed a clear decrease in situational awareness, the change in response time did not seem to be significant.

A unique aspect of this project is its use of a high fidelity car simulator, conducting interactive conversations with the test subjects, and testing two age groups. Many of the past studies used a very simple set-up, such as two pedals beside each other and a traffic light that flashed red[7]. The use of a car environment that is familiar to the subjects is expected to increase the accuracy of the results. In addition, only some of the studies conducted interactive conversations with the driver; some experiments only required the subject to listen to radio broadcasts of varying complexity, for example, a weather forecast and an emotional news broadcast. While most studies do include a variety of age groups, the studies were not aimed at determining the differences in driver response in two different age groups. Testing two age groups will aid in determining whether younger and older subjects experience the same risks from the cognitive and physical distraction caused by cell phone conversations. In addition, increasing the available database for older drivers will provide valuable information for ongoing projects at the MIT Age Lab.

4.0 Technical Approach

4.1 Overview

To meet the project objective, test subjects will be tested in the MIT Age Lab driving simulator; the overall set-up of the simulator is shown in Figure 1. The simulator is a modified Volkswagen Beetle with a large, high-resolution screen in front of the car. The screen is used to convey the testing scenario to the driver. The scenario to be run is input into the computer (seen in the foreground); the same computer is used for data collection. The conversations will be conducted through a real cell phone. The appropriate cell phone set-up – hand held or hands free – will be placed in the car for the driver to use (not shown). Once the testing starts, the driver will receive instructions only through the phone. One experimenter will be operating the computer, while the second experimenter will be conducting the conversation from a separate room. The surveys will be administered by the experimenter operating the computer.

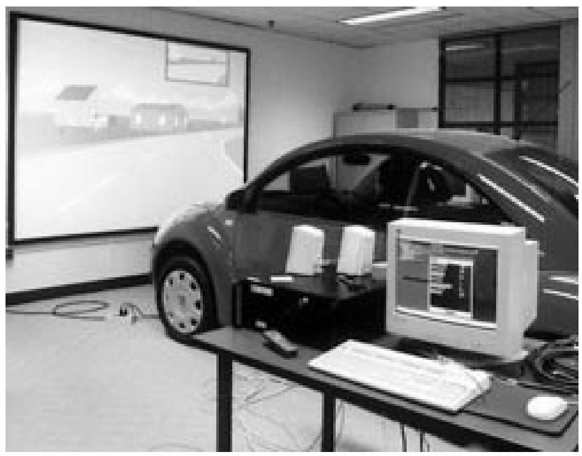

Figure 1. The MIT Age Lab car simulator set-up.

Table 1 shows a summary of the tests to be performed for each age group (young and older). The normal driving set-up is represented where the *None* for Phone Set-Up and *None* for Cognitive Loading meet. This normal driving test will be conducted both at the beginning and at the end of the testing. In Table 1, *RT* denotes Response Time and *SA* denotes Situational Awareness.

Table 1. Summary of set-ups and measurements to be taken.

Phone Set-up / **Cognitive Loading**	**None**	**Hands Free**	**Hand Held**
None	RT, SA	N/A	N/A
Low	N/A	RT, SA	RT, SA
Medium	N/A	RT, SA	RT, SA
High	N/A	RT, SA	RT, SA

Figure 2 shows a representational block diagram of the key features in the testing set-up, and how they interact. Inputs and outputs are indicated by the direction of the connecting arrows.

The *Phone Conversation* represents the cell phone conversation with the subject. The *Baseline Scenario Input* contains the high-level driving conditions, such as stretches of empty road and random scenery. The *Stimulus* are the stimulants used to test the response time and situational awareness of the driver, such as a person suddenly running onto the road or a Stop sign appearing. The *Car Dynamics Simulator* uses as inputs the driver's actions (from *Controls*) and calculates the new driving conditions and visual scene. The scene is continuously updated to conform to the actions of the driver. The C*ontrols* refer to the car subsystems, such as the braking system, speedometer, and wheel turning. The *Visual Scene Generator* combines inputs from the *Car Dynamics Simulator* and the *Stimulus*, and produces the scene on the *screen*. The *Phone Conversation*, *Car Dynamics*, and *Stimulus* feed into the data collection system from which the data of interest is output.

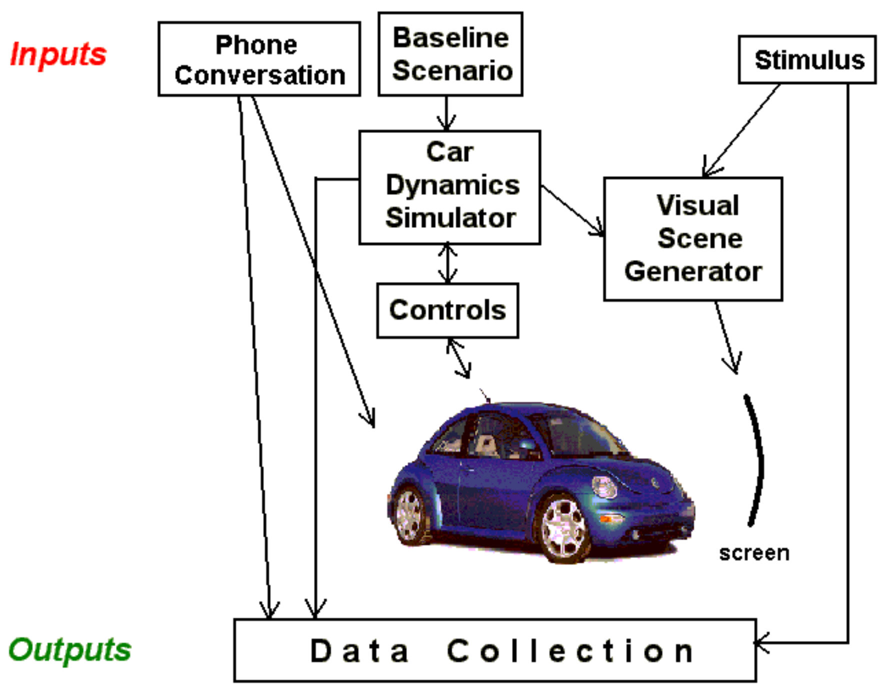

Figure 2. Block diagram describing the inputs and outputs of each component of the car simulator system. The direction of the arrow indicates inputs and outputs.

The key phases in the project are Design, which includes roadway design, conversation design for the various cognitive levels, survey design, and test matrix design; Build, which includes the coding of the roadway and pilot runs; Testing; and Analysis, which includes analyzing the data and making recommendations for minimizing the cognitive distractions caused by the cell phone conversations.

4.2 Design Phase

4.2.1 Roadway Design

The roadway is a key element in the driving experience, and is the means of showing the stimuli to the test subject. The roadway will be constructed from scene components already available for the MIT Age Lab car simulator[8]. Some examples of scene components are trees, cars, houses, Stop signs, and people. The scene components will be put together into driving sections; only a small percentage of the sections will contain a stimulus that tests response time or situational awareness. Examples of stimuli are a Stop sign and a person running onto the road. The driving simulation that is to be driven by the test subjects will consist of a number of driving sections in random order. The number and type of stimuli for each test set-up will be constant. The overall driving experience for each test subject will be the same.

To ensure that the main source of cognitive loading and distraction is due to the cell phone conversation, the road scenery will be minimized to reduce its possible distraction.

The use of the car simulator may cause “simulator sickness” in some of the test subjects; simulator sickness is similar to car sickness. The risk of the subjects experiencing simulator sickness will be minimized by decreasing the number of curves and hills in the road. In addition, a short break has been planned in the middle of the testing, thereby decreasing the chance of simulator sickness and also decreasing the effect of fatigue on the results. The total simulator time has been limited to 45 to 50 minutes.

Response time will be tested by a suddenly appearing Stop sign or a person suddenly running onto the road, and situational awareness will be tested by placing signs along the road and randomly asking what the last sign was. Even though the person suddenly running onto the road may elicit a different response in the subjects than the suddenly appearing Stop sign, this difference will be assumed to be minimal. However, to ensure that the testing is identical for all subjects, an equal number of each of these stimuli will be tested in each set-up. To minimize the likelihood of the test subjects being able to predict the occurrence of the stimuli, the appearance of driving sections containing the stimuli will be in a random order and many more signs will be placed than the number of times asked what the last sign was.

Figure 3 shows a sample roadway section. The section is 5min in length, which is the equivalent to the length of each set-up. The *Stimulus* are indicated by the red-coloured *STOP*, *PED*, and the rest star. *STOP* and *PED* represent the sudden appearance of a Stop sign and a pedestrian running onto the road, respectively. The *S* represent the showing of a sign, while the red stars are when the experimenter asks the subject as to what the last sign was. There are also a number of additional events shown. These events are used to ensure that the driver does not automatically stop when something red is seen or when a person appears. The additional events specifically placed in the timeline are a person dressed in red walking by the road without walking onto the road (*rped*), a pedestrian crossing with no pedestrians crossing (*pedx*), red cars (*rcar*), and people by the road (*peds*). In addition, various buildings, trees, cars, and people will be placed through the roadway to provide a more realistic setting.

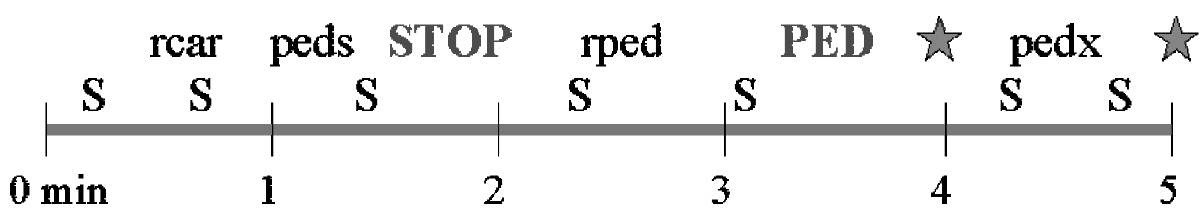

Figure 3. A sample roadway timeline for one set-up; 5 min in length.

4.2.2 Conversation Design

The test subject will be subjected to three levels of cognitive loading through questions of low, medium, and high difficulty. The same conversations will be used between subjects. Low cognitive loading will be imposed through small talk, with questions such as “Are you having a good day?" and "Are you looking forward to the weekend?" The conversation will be allowed to take its natural course, without the experimenter requiring the answer of a set list of questions. Appendix A.1 contains a list of questions and ideas that may be used as conversation starters, if needed.

Medium cognitive loading will be achieved by asking the subject to describe a movie of their choice. The experimenter will be asking questions related to the movies, thereby making this an interactive conversation. The conversation will not be scripted, but rather allowed to flow freely. Preferably the movie will be known to the experimenter. In the case that the experimenter is not familiar with any of the movies known to the subject, a book with movie synopses will be available, thereby allowing the experimenter to become familiar with the movie chosen by the subject. Appendix A.2 shows a list of movies known by the experimenters; the subjects will be asked to select a movie from that list.

High cognitive loading will be achieved by asking the subject to edit a paper on the phone. The paper will contain a variety of errors, including improper spelling, grammar errors, punctuation errors, and awkward wording. The experimenter will prompt the subject to suggest a new working, spell words, clarify the punctuation, and other editing activities. The subjects will be expected to have a good working knowledge of English, so that they will be able to edit the writing. The goal of the editing exercise is to cognitively load the subjects; therefore, their editing ability is not of importance because the edited piece will not be evaluated for the quality of writing. Appendix A.3 shows one of the High Cognitive Loading Editing Pieces to be used.

Since the tasks imposing the cognitive loading do not require specific knowledge of technical issues, the imposed cognitive loading should not differ between test subjects with different academic backgrounds. Some variations may be caused due to the personal background; however, these variations are expected to be minimal.

A post-testing survey will be used to determine the cognitive loading actually experienced by each test subject. While these personal evaluations cannot be converted into a reliable quantitative scale, the responses may help in explaining variations in response time and situational awareness between subjects. All conversations, which are composed of a specific task and questions for each cognitive level, will be recorded with a video camera.

4.2.3 Survey Design

A pre-testing and a during/post-testing survey will be designed for the subject to complete. The pre-testing survey will be used to collect background information about the test subject, such as age, cell phone usage, and driving experience. Appendix B.1 shows the Background Information Survey that will be used. The During/Post-Testing Survey will record the subject's perceived cognitive loading and her/his perceived driving ability throughout the driving simulation. The information will be used to compare the cognitive loading experienced by subjects, and as supplemental information on how safe the driver was during each cognitive loading level, respectively. It is expected that a driver who can correctly assess her/his driving ability is then be able to correct this situation if it is dangerous, and therefore is a safer driver. Appendix B.2 and B.3 show the During/Post-Testing Surveys.

During testing, the experimenter will evaluate the attentiveness of the subject, and will to some degree evaluate how well the driver performed at the task of keeping up with the conversation, providing a complete and coherent synopsis, and the carefulness and completeness in editing the text. These evaluations will be subjective responses, based a scale. Appendix B.4 shows the Experimenter's Survey.

All sections of the Design Phase have been completed.

4.3 Build Phase

4.3.1 Roadway Build

The designed roadway will be coded into the simulator. Though this coding process is simple, it may be very time consuming since every event (e.g. road conditions, buildings, trees, people, cars) must be specified and coded.

The code uses a set of pre-defined commands; the user chooses the parameters to be used within the command[9]. For example, using the *SIGN* command to program a Stop sign that is located 5170ft into the run, will appear as follows:

4800,	SIGN,	1,	370,	1,	0,	0,	0
Object will first appear when the car is *4800* ft into the run.	Object to be displayed is a *sign*.	Use "Road sign" type of sign.	Sign will appear *370* ft away.	Display single Stop sign.	US sign.	Sign on driver's side of road.	Rotation [deg].

Figure 4. Sample simulator code, coding for a Stop sign.

4.3.2 Pilot Runs

The pilot runs will be performed concurrently with building the roadway and will provide feedback on roadway design, the overall experiment timeline, and the actual cognitive loading imposed by each of the cognitive levels.

Judging the appropriate placement of events and stimuli in the roadway is very difficult without being able to perform pilot runs. The pilot runs will provide important information about the relative placement of stimuli within the experiment - whether the time between stimuli is sufficient for the driver to resume driving at the required speed and also be properly cognitively loaded; the degree of simulator sickness imposed by the roadway; whether the test run is of appropriate length, and how much distraction is caused by the additional events. Feedback from the pilot runs will be incorporated into the roads as they are being coded.

Pilot runs will allow the experimenters to become very familiar with running the experiment. This will result in both minimizing the subject testing time, and increasing the probability of running the experiment without any human errors.

Performing full pilot experimental runs will help in determining whether the currently designed cognitive levels impose the desired cognitive loading.

Feedback from the pilot runs will be incorporated into the appropriate parts of the study.

4.3.3 Test Subject Selection

Test subject selection aims to minimize the variability in the results due to differences in the personal and academic backgrounds of the subjects. The younger subjects will be 18 to 25 year old MIT students, providing a very homogeneous sample population. The older subjects will be more than 60 years of age. Since the cognitive loading tasks do not require specific technical knowledge, no specific selection in academic background will be required. However, subjects will be required to have a good working knowledge of English (determined subjectively) and have a minimum of one year of driving experience, with at least some driving experience in the last 3 months. Since overall driving ability is not being measured, but rather the changes in driving ability, the subjects need not be equally proficient in driving.

The gender of the subjects will not be considered in subject selection, since only some studies show longer reaction times for women, and in those cases the difference in reaction time is only 5-10% [10].

In total 24 subjects will be tested, with 12 subjects from each group.

4.4 Testing

4.4.1 Test Set-Up

The testing requires the test subject to drive while conversing on a cell phone; his/her responses are recorded by the simulator. The test set-up is outlined in section 4.1. The parameters in the digital output are velocity, acceleration and deceleration, braking, and turning. Additional parameters may be output if it is deemed necessary.

4.4.2 Independent Variables and Test Method

The independent variables in this study are age of the test subjects, phone set-up, and level of cognitive loading. The same tests will be run for the younger and older subjects. The phone set-ups are talking on a hands free cell phone, driving normally (not conversing), and talking on a hand held cell phone. The latter two set-ups are control runs. The normal driving set-up is required since the aim is to measure changes in driving ability, rather than measure one's overall competence at the task. Since this set-up will not involve any conversing, there will be no change in cognitive loading. The second control set-up of driving while talking on a hand held cell phone is required for distinguishing between physical and cognitive distractions when the three set-ups are compared. The hands free cell phone set-up provides a measure of the cognitive distractions as it eliminates the physical distractions.

In each of the two set-ups that involve conversing on a cell phone, the subjects will be asked to converse on topics which impose low, medium, and high cognitive loading, as described in section 4.2.2.

Each test run will measure quantitative responses – response time and situational awareness – and qualitative responses – the driver's own opinion of her/his driving performance. Response time refers to the time required for a person to process a stimulus before reacting to it. Reaction time will be measured as the time elapsed between when an easily perceptible stimulus is presented, until the driver reacts to the stimulus by braking, accelerating, decelerating, or turning the wheel.

In this project, situational awareness is used as a measure of how attentive and observant the driver is of his/her surroundings. Since situational awareness is a concept, rather than having a quantitative definition, there is no unique method for it to be measured. In this project, situational awareness will be tested by placing sign along the road, and periodically asking the subject to recall what the last sign was. Situational awareness will be measured through a boolean "true" or "false" for the test subject correctly identifying the sign or incorrectly identifying the sign, respectively. Only changes in situational awareness from the normal driving set-up will be looked at, as the person's overall situational awareness will not provide any information on the impact of cells phones on driving ability.

Figure 3 shows a sample timeline from a run that tests the driver's response time and situational awareness. The car in each frame represents the car simulator in which the subject is seated. The run in Figure 3 tests response time at *t=10s*, and situational awareness at *t=40s*. Note that on the timeline, the output shows that the driver pressed the brakes at *t=11s*, which gives a response time of 1s. The driver was asked about the type of sign seen 20s after the sign was presented.

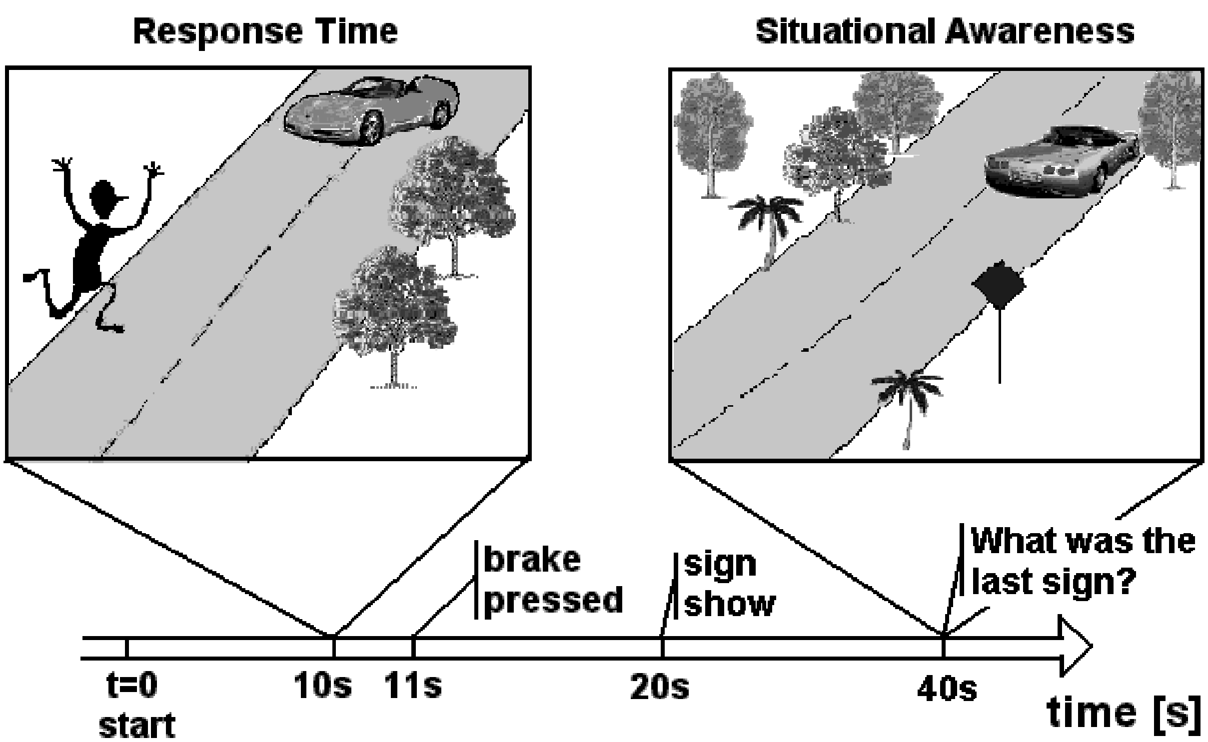

Figure 4. A sample timeline from a scenario. Response time is tested by a person suddenly running onto the road, while situational awareness is tested by asking what the last sign was.

Each subject will complete the pre- and post-testing surveys. These qualitative responses will be correlated with the quantitative responses.

4.4.3 Data Collection

The data will be collected by the computer connected to the car simulator. The data output will be from the *Phone Conversation*, *Car Dynamics*, and *Stimulus*, as shown in Figure 2. The data from the *Car Dynamics* will be correlated with the timing of the appearance of the *Stimulus* and the different levels of cognitive loading through the *Phone Conversation*. This combined data set will allow the measurement of response time and situational awareness of the subject. For each test run (consisting of a given phone set-up and a cognitive level), the subject's response time and situational awareness will each be tested two times. The response time will be tested by both a person suddenly running onto the road and a suddenly appearing Stop sign during each test run.

Data from the surveys will be collected in the form of a value within a specified scale, as described in Appendix B. These values will be tabulated. The same process will be used for the subjective evaluation of the subjects by the experimenters.

The devised testing method takes into account the learning curve of subjects and accruing fatigue as the experiment progresses. The possible errors are discussed in section 4.4.4, with the steps being taken to minimize these errors.

4.4.4 Sources of Error

The two main types of errors in this experiment are instrumental and human related. The instrumental errors refer to the measurement inaccuracies of instruments; the human related errors refer to the introduction of errors and random variability in the results due to the use of human subjects. Within these two categories, there are four sources of error for the project: errors inherent in the data collection and recording by the car simulator; improvement of the subject's driving skills as s/he learns how to operate the simulator (the learning effect); high variability in the data due to the small sample size of subjects, compared to the population of drivers, resulting in lower statistical significance; and subjectiveness in responding to personal assessment surveys.

4.4.4.1 Instrument Errors

The car simulator is capable of collecting data at 60Hz (0.0167s resolution) for all applicable parameters. The average response time for pressing the brake pedal is about 0.8 seconds[11]; however, this number can be significantly larger depending on the conditions (for example, during cognitive distraction). The error introduced in the data recording by the simulator is not significant, since the human response time is more than 50 times greater than the error of the simulator caused by its data collection resolution. Instrument errors are not considered a significant source of errors in this experiment.

4.4.4.2 Human Related Errors

The learning effect is considered the most significant source of error. Learning is inevitable in any task, and the effect cannot be completely removed from any experiment. Learning occurs when a person repeatedly performs a task: while the difficulty of the task remains constant, the time required for the person to complete the task decreases. Due to learning, the subject will become increasingly proficient at the driving task, and therefore, her/his response time decreases. While in some cases the learning effect may be obvious from the trend in the data, in most cases this effect will not be easily discernable.

The effect of learning on the results can be minimized by allowing the test subjects to become accustomed to the driving simulation and counterbalancing the order of the test runs. Table 2 shows the testing order for one Test Sub-Group (N=4); all procedures for decreasing the learning effect have been incorporated. The subjects will be allowed to become familiar with the simulator by practicing in it. The learning is counterbalanced between the test subjects by reversing the order of the testing procedure. As shown in Table 2, Subject 1 first completes the hand held phone conversations, and then uses a hands free phone. For Subject 2 this order has been reversed. In addition, the order of change in cognitive levels is counterbalanced. Subject 1 is subjected to increasing levels of cognitive loading, while Subject 3 is always subjected to decreasing levels of cognitive loading. The averaging of the results is expected to provide response time and situational awareness trends that are closer to the ideal no learning effect trends. While this approach will certainly not correct all the errors due to the learning effect, it will minimize them. In addition, a short break is planned between the two phone set-up runs. This is expected to decrease the effect of fatigue on the results. The learning effect will be quantified by measuring the responses of the subjects during normal driving, both at the beginning and at the end of the testing. The change in response time and situational awareness between these two runs will show the hysteresis in the data, which will be equal to the magnitude of the overall change in reaction due to learning and fatigue. However, the magnitude of the hysteresis will not provide any information about the cause of the change in responses, such as, what fraction is due to learning compared to fatigue.

Table 2. Counterbalanced testing order for one Test Sub-Group.

Subject 1	**Subject 2**	**Subject 3**	**Subject 4**
Practice Driving	Practice Driving	Practice Driving	Practice Driving
Normal Driving	Normal Driving	Normal Driving	Normal Driving
Hand Held Phone: Easy Medium Difficult	Hands Free Phone: Easy Medium Difficult	Hand Held Phone: Difficult Medium Easy	Hands Free Phone: Difficult Medium Easy
Short break (administer survey)			
Hands Free Phone: Easy Medium Difficult	Hand Held Phone: Easy Medium Difficult	Hands Free Phone: Difficult Medium Easy	Hand Held Phone: Difficult Medium Easy
Normal Driving	Normal Driving	Normal Driving	Normal Driving

Variability is present within any population. Human experimentation utilizes only a very small subset of the population, which may not be representative of the overall population. Depending on the sample size (number of subjects, *N*) and the persons chosen for the study, the variability may be much larger than the normal population. Data with high variance usually has low statistical significance. To increase statistical significance, the number of subjects in the study, *N*, should be increased. The collected data must be validated by determining its statistical significance before looking for trends in the data. The T-test and Analysis Of Variations (ANOVA) will be used to test statistical significance.

The post-testing survey will help in calibrating the differences in cognitive loading experienced between individuals. However, in the survey, errors can arise because individuals may answer or rank questions in a different fashion as a result of interpretation differences rather than actual difference in their evaluations. The survey is meant to provide additional insight into the results, and will be viewed as such, rather than as a definitive document. The surveys are not expected to be a very large contributor of error to the final results.

A final source of error is improper analysis and interpretation of results by the experimenters. While such errors are possible, all efforts will be made to prevent them from occurring through the very careful design of the experiments, careful and thorough recording of all decisions made and actions taken, and reviewing the calculations and procedures. Improper analysis is not expect to be a significant source of error.

4.5 Data Analysis

4.5.1 Statistical Significance

The results will first be analyzed for statistical significance. Statistical significance indicates the likelihood that a difference between two sets of data is not due to sampling error, that the observed trends are generalizable, and that the difference in results in the two sets is not likely to have occurred by chance. In an experiment involving human testing, the results may not be statistically significant due to the natural variation in humans and the small subset of the population that is tested during the experiment. If statistical significance is established, the results will be analyzed for the changes of response time and situational awareness with changing cell phone set-up and cognitive loading.

4.5.2 Changes in Response Time and Situational Awareness

The data will be analyzed for changes in response time and situational awareness with changing cognitive loading. The relative importance of cognitive and physical distractions on the driving ability of the subjects will be compared. This comparison will be key in determining what measures should be taken to reduce the distraction and risk caused by cell phone usage.

4.5.3 Survey Analysis

The post-testing survey results will be used to determine the perceived cognitive loading, and to compare perceived driving ability to actual driving ability. The experimenter's evaluations will be used to assess how the subject shifted her/his attention between tasks depending on the situation.

Due to the variations in background between subjects, the imposed cognitive loading may not be identical between subjects. A record of the person's perceived cognitive loading can help in determining inconsistent and unreliable points in the data during data analysis. For this analysis, it is assumed that the perceived cognitive loading is closely representative of the actual cognitive loading.

The subjects' perceived driving ability will be compared to their actual driving performance. A driver who is aware of the distractions in her/his environment and how these stimuli are affecting his/her driving performance is able to alter his/her behaviour in a manner consistent with decreasing the risk of an accident. The driver's perceived performance versus actual driving performance will be used as an additional metric of the impact of cell phone usage on driving ability. The evaluations by the experimenter will be used in a similar fashion to evaluate the impact of cell phones on driving. A driver who re-prioritizes mental loading tasks and pays less attention to the conversation during a demanding driving situation is more likely to avoid an accident. Pauses in the conversation and lack of coherence in the sentences will be used as an indication that the subject is paying less attention to and putting less effort in to the conversation aspect, thereby paying more attention to the driving task.

4.6 Recommendations for Decreasing Cognitive Loading

As the results are analyzed, the most substantial causes of distraction may become apparent. If possible, recommendations will be made on how to decrease the distractions caused by cell phone usage, thereby promoting a safer driving environment. The recommendations will be tested time permitting and if the testing is viable.

5.0 PLANNING

5.1 Safety Issues

This project will use humans as test subjects, which requires the permission of the Committee On the Use of Humans as Experimental Subjects (COUHES) at MIT. This permission has already been obtained through the MIT Age Lab, who have a blanket permission. As is consistent with all human experiments, the subject will be allowed to stop the experiment at any point. All other COUHES and MIT Age Lab regulations will be strictly followed.

The main source of discomfort that may be experienced by the test subjects is simulator sickness, as discussed in section 4.2.1. All possible precautions will be taken to minimize the possible discomfort experienced by the subjects.

5.2 Facilities and Resources

Table 3 lists the resources and facilities required and the current status of their availability. The key facility in the project is a Car Simulator; the use of a car simulator has been secured from the MIT Age Lab. Analysis software and equipment have been secured at the MIT Dept. of Aeronautics and Astronautics. The student test subjects will be solicited from volunteers. The older test subjects will be solicited by the MIT Age Lab. No difficulties are anticipated in soliciting subjects.

Table 3. Facilities and resources.

Required Facility or Resource	Status of Availability
Car Simulator	Available; MIT Age Lab.
Analysis software and equipment	Available; Aero/Astro Dept.
Test Subjects: young	MIT student volunteers.
Test Subjects: older	To be solicited by MIT Age Lab.

5.3 Budget

The budget for this project is described in Table 4. The actual cost of project is estimated at $100 US. The real world cost of this project would be about $7,370. Currently the cell phone and the car simulator time have been obtained. The cell phone hands free adapter and video tapes are to be purchased in the beginning of February. The Video Camera will be obtained and Test Subjects will be solicited at that time. The miscellaneous expenses include expenses such as photocopying and advertising for subjects. No problems are anticipated in obtaining the required funds.

Table 4. Budget

Item	Means of Acquiring	Actual Cost	Real World Cost
Cell phone	On loan.	---	$200
Hands free cell phone set	To be purchased.	$30	$30
Test subjects: young	Donated time.	---	$120
Test subjects: older	MIT Age Lab.	---	$600
Car Simulator Time	MIT Age Lab.	---	$6,000
Video Camera	On loan.	---	$350
Video tapes (10)	To be purchased.	$40	$40
Miscellaneous	To be purchased.	$30	$30
	Total:	**$100**	**$7,370**

Note: All costs are in US dollars.

5.4 Schedule

The project schedule is shown in Table 5. The experimental design, which includes roadway, conversation, and survey design, has already been completed. The Build phase will start on Feb. 7, and will continue through the end of February. The Build phase will be composed of coding the roadway and doing pilot runs. At that time, testing of young and older subjects will commence, and is expected to continue until April 10th. An estimated total of 36 hours of testing will be required. This gives a margin of 2 weeks before the last day to collect data. Concurrently with testing subjects, the collected data will be formatted and analyzed to the extent possible. This analysis will be most important in determining if any of the collected data sets are unusable and the same set of measurements must be collected from another test subject. The data analysis, which includes quantifying the learning effect (hysteresis), testing for statistical significance, and interpreting the data, will continue through April 24th. At this time, the preparation of the oral report and the writing of the written report will be underway. The written report will be completed by May 14th.

Table 5. Schedule.

Task	Start	End	Feb.	Mar.	Apr.	May
Roadway Build	Feb. 7	Feb. 21				
Pilot Runs	Feb. 14	Mar. 1				
Test Young Subjects	Mar. 1	Apr. 10				
Test Old Subjects	Mar. 1	Apr. 10				
Data Analysis:	Mar. 1	Apr. 24				
Learning & hysteresis	Mar. 1	Apr. 24				
Statistical Significance	Mar. 8	Apr. 24				
Survey Analysis	Mar. 8	Apr. 24				
Trend Analysis	Mar. 16	Apr. 24				
Recommendations	Apr. 10	Apr. 24				
Report:	Apr. 10	May 14				
Oral	Apr. 10	May 8				
Written	Apr. 10	May 14				

6.0 CONCLUSION

This project will test the effect of cell phone conversations on one's driving ability through the testing of response time and situational awareness in two age groups. The Design phase of the experiment has been completed; the results of the design have been presented in this document. The Build, Testing, and Analysis phases are to be performed in the Spring of 2002. This document has shown the readiness level for continuing with the Build phase of the project and the current state of planning. The facilities and resources, budget, and schedule show the feasibility and planned steps in the project. The project will be completed by May 14th, 2002.

7.0 ACKNOWLEDGEMENTS

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8.0 REFERENCES

1. Moore, L.R., and G.S. Moore. "The impact of cell phones on driver safety", *Professional Safety*. June 2001, **46** (6), pp. 30-32.

2. Buris, M. and A. Cain. "Investigation of mobile phones while driving." Tampa, FL: University of South Florida, Center for Urban Transportation Research, April 1999.

3. National Conference of State Legislatures (NCSL). "Cell phones and highway safety: 2000 legislative update." Denver: NCSL, 2000.

4. McCarley, J.S., Vais, M., Pringle, H., Kramer, A.F., Irwin, D.E., Strayer, D.L., 2001. "Conversation Disrupts Visual Scanning of Traffic Scenes", *in press*.

5. Strayer, D.L., Drews, F.A., Albert, R.W., Johnston, W.A., 2001. "Cell Phone Induced Perceptual Impairments during Simulated Driving", *in press*.

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

7. Irwin, M., Fitzgerald, C., Berg, W., 2000. "Effect of the intensity of wireless telephyone conversations on reaction time in a braking responses". *Perceptual and Motor Skills*. **90**, 1130-1134.

8. Extensive information about the programming of roadways and the functioning of the simulator are available at http://mit.edu/16.400/www/auto_sim/Help/Introduction.htm and other files in the same directory; Last accessed Dec. 10, 2001.

9. Tatsuki Kashitani, "Automobile Simulator Lab". In http://mit.edu/16.400/www/auto_sim/sample_roadway.pde; last accessed Dec. 10, 2001.

10. American Automobile Association, Traffic Engineering Safety Department, Reaction Time as Related to Age, Report No. 69, 1966.

11. Charles C. Roberts, Jr., "Response Time". In http://ourworld.compuserve.com/homepages/charles_c_roberts_jr/respon.htm; last accessed Oct 12, 2001.

Appendix A

Appendix A.1 Low Cognitive Loading questions

The conversation will be allowed to follow its natural flow. These questions will be used as conversation starters if the conversation comes to a natural stop.

How are you today?

What did you do last weekend?

Are you looking forward to this weekend?

What year are you in?

What do you study? (Ask for more details)

What's your favourite class?

Where do you live?

What's your favourite activity?

What's your favourite food?

What type of music do you like?

Where is home?

What are you doing for the summer?

Appendix A.2 Medium Cognitive Loading: list of movies, operas, etc

Titles with an * represent movies that are known by both experimenters. Titles without an asterisk are known by Margarita Marinova.

Movies

A Cinderella Story
Robin Hood: Prince of Thieves *
Gladiator *
Sleepless in Seattle *
The Road to El Dorado
Back to the Future *
Citizen Kane
As Good As It Gets *
A. I.
Breakfast at Tiffany's
What's Love Got to do With It *
Memories of an Invisible Man
The Lion King *
When Harry Met Sally *
American Beauty *
Monty Python & the Holy Grail *
There is Something about Mary *

The Phantom Menace
Apollo 13 *
K-Pax
Chocolat *
Unbreakable *
The Abyss
Fight Club *
Meet the Parents *
The Birdcage
What Women Want *
Red Planet
The Little Mermaid *
Goldeneye *
Grease *
Sister Act *
Nine Months *
Terminator *

You Have Mail *
Top Gun *
Independence Day *
Toy Story *
Total Recall *
Ghost *
Amadeus
Mrs. Doubtfire *
The Mask *
Air Force One *
The Nutty Professor *
Waiting to Exhale *
Star Trek: Generations
Now & Then *
That Thing You Do *
2001: A Space Odyssey
Aladdin *

Plays, Operas, Ballets, etc.

Rent *
The Marriage of Figaro *
The Magic Flute

Miss Saigon *
The Nutcracker *
Swan Lake

Madame Butterfly
Annie (Musical)

Appendix A.3 High Cognitive Loading Editing Piece

(Italicized words are reminders for words where spelling or other grammatical questions can be asked.)

New materials with increasingly good properties are coming up all the time. However, for such a material to be used in manufacturing a thing, extensive testing and corroboration is required; the testing usually requires 5 to 10 years, and costs a lot, like $100M. The high amount of money needed, and the long time it takes to test a material, means that you can't use a material until much later than its invention, which is a problem since then you can't use it for defense and commercial structures. A material can't be used unless it's extensively tested and then certified by the powers that be. This causes a long, long wait between the light bulb going off in someone's head, until that idea can actually be built cool structures like a truss or a chair.

The Accelerated Insertion of Materials - Composites (AIM-C) is a project sponsored by DARPA (Defense Advanced Research Projects Agency) and Boeing, that wants to figure out some way of make the time needed to certify a material be shorter than what it is right now, but not really a a week or anything. But they want to make the testing time significantly shorter. This accelerated pace is going to happen by coding stuff into the computer that can say "hey! this is what will happen!" and that you can tell it "I am building a chair" and it will tell you what will happen. The current stuff in computers doesn't always answer your questions, and then sometimes *it's* wrong, and what use is it then anyways?

Appendix B

Appendix B.1 Background Survey

To be completed for each cell phone set-up

Background Survey

A) General Information

Name: ________________________ E-mail:________________________

Age: ________________________ Address:________________________

Sex: Male Female Phone Number:_________________

B) Driving Experience

Years of Driving Experience: ____________

How often have you driven in the past 3 months?

Once/Month Once/Week Once/Day

C) Cell Phone Experience

Do you own a cell phone?

Yes No

If yes, how long have you owned one?___________

Do you use a cell phone while driving?

Yes No

D) Writing Experience

How proficient are you in Writing English?

1	**2**	**3**	**4**	**5**
Never Write		Occasionally Write		Published Work

E) Movies

Please pick 4 movies out of the attached list that you would feel comfortable talking about. If you do not know any of those movies, please write down 4 movies that you would feel comfortable talking about.

1)_____________________________

2)_____________________________

3)_____________________________

4)_____________________________

Appendix B.2 Difficulty of Conversation Survey
Completed for each cell phone set-up.

Difficulty of Conversations

Hands Held

Conversation A: *Small Talk*
Conversation B: *Movie Description*
Conversation C: *Editing*

In terms of difficulty, how do each of the conversations rate? Please place your easiest of the three conversations at 1 and your hardest at 10.

Conversation A

1 2 3 4 5 6 7 8 9 10

Conversation B

1 2 3 4 5 6 7 8 9 10

Conversation C

1 2 3 4 5 6 7 8 9 10

Hands Free:

Conversation A: *Small Talk*
Conversation B: *Movie Description*
Conversation C: *Editing*

In terms of difficulty, how do each of the conversations rate? Please place your easiest of the three conversations at 1 and your hardest at 10.

Conversation A

1 2 3 4 5 6 7 8 9 10

Conversation B

1 2 3 4 5 6 7 8 9 10

Conversation C

1 2 3 4 5 6 7 8 9 10

Appendix B.3 Driving Self-Evaluation Survey

Driving Self-Evaluation: Hand Held Set-up

Driving: Hand Held:

Conversation A: *Small Talk*
Conversation B: *Movie Description*
Conversation C: *Editing*

How do you think you drove during the *normal driving* scenario?

1	2	3	4	5	6	7	8	9	10
Very Dangerously		Dangerously		Satisfactory			Safely		Overly Safely

During Conversation A?

1	2	3	4	5	6	7	8	9	10
Very Dangerously		Dangerously		Satisfactory			Safely		Overly Safely

During Conversation B?

1	2	3	4	5	6	7	8	9	10
Very Dangerously		Dangerously		Satisfactory			Safely		Overly Safely

During Conversation C?

1	2	3	4	5	6	7	8	9	10
Very Dangerously		Dangerously		Satisfactory			Safely		Overly Safely

Driving Self-Evaluation - Hands Free Set-up

Driving: Hands Free:

Conversation A: *Small Talk*
Conversation B: *Movie Description*
Conversation C: *Editing*

How do you think you drove during the *normal driving* scenario?

1	2	3	4	5	6	7	8	9	10
Very Dangerously		Dangerously		Satisfactory			Safely		Overly Safely

During Conversation A?

1	2	3	4	5	6	7	8	9	10
Very Dangerously		Dangerously		Satisfactory			Safely		Overly Safely

During Conversation B?

1	2	3	4	5	6	7	8	9	10
Very Dangerously		Dangerously		Satisfactory			Safely		Overly Safely

During Conversation C?

1	2	3	4	5	6	7	8	9	10
Very Dangerously		Dangerously		Satisfactory			Safely		Overly Safely

Appendix B.3 Experimenter's Evaluation Survey
(To be completed for each cell phone set-up and cognitive loading level.)

Experimenter Evaluation: Subject Attentiveness

A) General Information

Name: ________________________

Age: ________________________

Sex: Male Female

Hand Held

Conversation A: *Small Talk*
Conversation B: *Movie Description*
Conversation C: *Editing*

How attentive was the subject during each of the conversations?

Conversation A

1	2	3	4	5
Not coherent; very broken conversation	Frequent/ long pauses	Occasional /longer pauses; some sentences do not make sense	Very few pauses	Fluent conversation/ no pauses

Conversation B

1	2	3	4	5
Not coherent; very broken Conversation	Frequent/ long pauses	Occasional/ longer pauses; some sentences do not make sense	Very few pauses	Fluent conversation/ no pauses

Conversation C

1	2	3	4	5
Not coherent; very broken conversation	Frequent/ long pauses	Occasional/longer pauses; some sentences do not make sense	Very few pauses	Fluent conversation/ no pauses

Hands Free

Conversation A: *Small Talk*
Conversation B: *Movie Description*
Conversation C: *Editing*

How attentive was the subject during each of the conversations?

Conversation A

1	**2**	**3**	**4**	**5**
Not coherent; very broken conversation	Frequent/ long pauses	Occasional /longer pauses; some sentences do not make sense	Very few pauses	Fluent conversation/ no pauses

Conversation B

1	**2**	**3**	**4**	**5**
Not coherent; very broken Conversation	Frequent/ long pauses	Occasional/ longer pauses; some sentences do not make sense	Very few pauses	Fluent conversation/ no pauses

Conversation C

1	**2**	**3**	**4**	**5**
Not coherent; very broken conversation	Frequent/ long pauses	Occasional/longer pauses; some sentences do not make sense	Very few pauses	Fluent conversation/ no pauses