An Evaluation of Driver Reactions to New Vehicle Parking Assist Technologies Developed to Reduce Driver Stress

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ABSTRACT

A wide range of advanced technologies are currently being introduced into production automobiles that are intended to increase safety and comfort. If effectively implemented, some of these advanced technologies also offer the possibility of reducing driver stress. This study employed heart rate as an objective physiological arousal measure along with more traditional self-report ratings to evaluate the extent to which two recently introduced technologies impact driver stress levels. The technologies evaluated were a semi-autonomous system for parallel parking that detects appropriately sized parking spaces and actively steers the vehicle into the parking space while the driver controls the throttle and brake and a cross traffic warning system designed to alert drivers of encroaching vehicles when backing out of parking spaces. Two separate samples of 42 participants each were employed in the analysis and each sample consisted of three gender balanced age groups (20-29, 40-49 and 60-69). In both experiments, each participant experienced multiple exposures to the parking maneuver with and without the technology (within subject design). After becoming familiar with the technology, participants rated their stress levels significantly lower when using the assistive parallel parking technology ($p = .025$) and physiological recordings showed an average heart rate 12.6 beats per minute lower ($p < .001$) providing confirmation of a lower state of arousal. These findings were consistent across gender and age groups. Mean self-report and heart rate data were suggestive of some reduction in stress levels with the cross traffic warning system, although these differences were not statistically significant ($p > .05$). It was observed that drivers were more likely to appropriately stop and yield to an approaching vehicle during trials when the cross traffic alert system was active, potentially reducing the likelihood of accidents. While ratings of the systems were generally positive, some individuals experienced issues with the technologies. Additional analysis of self-report data and subgroups within the data study sample is ongoing. Developing a more complete understanding of why some individuals have issues interacting with these types of new technologies may provide important insight into how further gains in technology adoption and stress reduction can be obtained.

INTRODUCTION

A reasonable case can be made on the basis of polling and surveys that today's drivers are experiencing greater levels of anxiety than in the past, arising from factors both inside and outside of the vehicle. This is due in part from chronic stressors in individuals' daily lives combined with longer commute times, increased driving demands due to traffic congestion, more frequent use of communication devices in the car and deteriorating infrastructure. Not only does such stress impact our arousal levels while driving (White & Rotton, 1998), but it can have enduring negative emotional effects that impact post-driving behavior (Hennessy, 2008; Van Rooy, 2006). Whereas spending time in the automobile for a drive into the country or just around the community was once seen as a source of escape from the pressures of daily life, seemingly simple acts such as parking a car along a city street or backing out of a crowded parking lot can be significant sources of added stress.

Stress can arise from a variety of sources. One source is the amount of actual effort that has to go into carrying out a task. The greater the amount of physical effort or mental concentration that is required, the greater the total workload on the driver (Brookhuis & De Waard, 2001; Wickens & Hollands, 2000). Another source of stress is the level of uncertainty about one's capability to successfully carry out a task or maneuver and the associated anxiety around the risk or error or failure (Matthews, 2002). In the case of operating an automobile, the risk of getting into an accident raises concerns ranging from the costs of repairing dented bumpers and increased insurance premiums to very realistic threats associated with more serious accidents.

By identifying specific situations and the physiological effects they have on the driver, we have been exploring concepts and technologies that offer the potential to bring the driver from a heightened stress level back to an optimal operational state and thereby make their time in the automobile safer and more comfortable (Coughlin, Reimer, & Mehler, 2009; Reimer, Coughlin, & Mehler, 2009). While some of the technologies that we envision for actively monitoring and encouraging a state change in the driver will take some time to be fully realized in production vehicles, there are advanced driver assistance systems being introduced now that are intended to promote wellbeing by reducing the amount of stress associated with particular tasks and maneuvers (see Lindgren & Chen, 2006 for a review). Examples range from semi-autonomous technologies such as adaptive cruise control that automatically adjusts vehicle speed to maintain a safe headway distance from a lead vehicle to blind spot identification systems that provide operators with warning information on the presence of vehicles hidden from their field of view. While part of the challenge of developing and implementing such systems is technical, equally important considerations include the behavioral aspects of use and acceptance. For example, to what extent is the general public willing and able to learn how to engage with new systems, appropriately trust such technologies, or actually use the systems in ways that produce the intended benefits? This may be particularly the case for older drivers for whom many of these technologies represent significant challenges to their mental models of how to operate a vehicle and who may be less trusting of new technologies per se. Braitman, McCartt, Zuby and Singer (2010) note that several early reviews of some driver assistance technologies where the systems were rated as annoying and drivers turned off the systems. Other work suggests that drivers tend to ignore information presented by systems (Hurwitz et al., 2010), adapt driving styles to compensate for the added security (Lindgren & Chen, 2006).

Research in our lab has demonstrated that physiological and eye tracking measures can be utilized as sensitive indices of changes in driver cognitive workload, arousal and stress. In (Coughlin et al., 2009; Mehler, Reimer, Coughlin, & Dusek, 2009) we proposed that physiological measures can be used in assessing the relative demand placed on the driver by various comfort, safety systems and in-vehicle interfaces. As we noted in Coughlin et al. (2009), "integrating these assessment methodologies into the development process should aid manufacturers in selecting optimized designs with the least demand on the driver, resulting in greater user satisfaction, increased safety, and less stress." This research aims to extend upon the building blocks of earlier work to assess stress levels with two new assistive technologies that have recently been introduced in passenger automobiles.

This report covers the initial findings of two experiments undertaken to evaluate drivers' reactions to two assistive technologies developed to promote a more relaxed driving experience. The first is a semi-autonomous system for assisted parallel parking and the second is a cross traffic alert system designed warn drivers of encroaching vehicles when they are attempting to back out of parking spaces in a parking lot, garage or driveway. Both parallel parking and backing out of parking spaces represent low-speed maneuvering challenges that most drivers confront on a frequent basis. While many drivers appear quite comfortable in these situations, others find them as added sources of stress in already busy schedules and some individuals will go out of their ways to avoid having to undertake either task. If assistive technologies are able to reduce the workload and/or anxiety associated with such tasks, they not only offer the potential for reducing driver stress but may also increase the mobility of individuals who might otherwise restrict their driving to avoid such situations.

An important aspect of the evaluation methodology employed in the project is the collection of objective physiological data on the stress levels associated with using the technologies in addition to more traditional self-report ratings and evaluations. While self-report evaluations are important sources of information on individuals' perceptions and feelings about their interactions with technologies, there can be a question about the degree to which research participants may be biased toward "helping" the research by providing answers they think the researchers are attempting to find. By monitoring participants' physiological arousal levels while engaged in the parking tasks with and without the assistive technologies, we obtain data that can be used to validate the extent to which self-report information represents a reliable evaluation of their experience. Heart rate was selected as a relatively unobtrusive measure that we have found to be highly sensitive to incremental increases in workload and stress in both driving simulation and on-road driving studies (Mehler, Reimer, & Coughlin, 2010; Mehler et al., 2009; Reimer, Mehler, Coughlin, Godfrey, & Tan, 2009).

METHODS

Apparatus

As already noted, this project was designed to evaluate participants' subjective and objective reactions to two parking technologies that have recently been introduced into high-end production vehicles. A 2010 Lincoln MKS with Eco Boost™ was used as the test platform. The vehicle was equipped with the original equipment manufacturer (OEM) forward and reverse sensing system, Rear View Camera and Active Park Assist™ (APA). A Blind Spot Information System (BLIS™) with Cross-Traffic Alert™ (CTA) was installed in the vehicle following the OEM specifications for the 2012 Lincoln MKS. The vehicle was instrumented with a customized data acquisition system for time synchronized recording. Sensors included six channels of video capturing the vehicle surroundings and driver behavior, in-vehicle audio, a controller area network (CAN) bus data link for accessing embedded vehicle telemetry, global positioning (GPS), FaceLAB 5 eye tracking system (Seeing Machines, Camberra, Australia) and a MEDAC System/3 physiology monitoring instrument (NeuroDyne Medical Corp., Cambridge, MA). The data acquisition system included functionality for playing recorded audio through the vehicle sound system. At all times when a participant was driving, a research associate was seated in the rear of the vehicle. The research assistant was responsible for ensuring: safe vehicle operation, that participants understood and followed instructions, recording telemetry was working properly and that the experiment proceeded according to a predefined script. In both experiments, the research assistant used a series of key presses at predefined trigger points to transition between steps in the experiment. This ensured that instructions and parking tasks were presented at consistent points without being impacted by surrounding traffic conditions or participant behavior, e.g. slow driving or difficulty parking. Conversation between the participant and research associate was kept to a minimum.

For EKG recordings, a modified lead II configuration was employed; the negative lead was placed just under the right clavical (collar bone), the ground lead just under the left clavical, and the positive lead on the left side over the lower rib. The skin was cleaned with isopropyl alcohol and standard pre-gelled silver/silver chloride disposable electrodes (Vermed A10005, 7% chloride wet gel) were applied.

Subjects

To examine the possible effect of age, participants were recruited from three gender balanced age groups (20-29, 40-49 and 60-69). Participants were required to be active, experienced drivers, defined as driving 3 or more times a week and having held a valid driver's license for 3+ years. Additionally, participants needed to demonstrate a safe operating history by reporting a driving record free of accidents for the past year. They had to report being comfortable driving a full-sized sedan such as a Ford or Lincoln as part of the study and be willing to parallel park the test vehicle (Experiment 1) or back the test vehicle out of a parking space (Experiment 2). The participant group was considered to be relatively healthy compared to an unscreened community sample based on self-report and specified health exclusion criteria including: a variety of major cardiac conditions, hospitalization in the past 6 months, neurological problems, taking medications that cause drowsiness or suggest safety concerns (e.g. anti-psychotic, anti-convulsant medications, anti-depressants, anti-anxiety). Participants were drawn from a research subject database, a list of community volunteers in the greater Boston area who have in the past responded to online, print advertisements or referrals and agreed to register for potential participation in laboratory studies.

Procedure: Experiment 1 – Active Park Assist™ (APA)

As detailed in figure 1, study sessions were divided into several segments. Key components of the protocol included questionnaires before, during and following participants' experience with the APA technology, a briefing to introduce the concepts and operation of the technology before entering the vehicle, a research associate demonstration of selected technologies, a period of driving the vehicle to gain experience with the basic maneuvering characteristics and promote habituation to the novelty of driving the vehicle, a series of at least three each "practice" parallel parking trials with and without APA technology active followed by a series of three "scored" parks each with and without the APA technology active.

The pre-experimental questionnaire was administered prior to a detailed briefing on the technology to capture background information on participants and their exposure, experience and expectations surrounding various technologies. A detailed briefing on the of the APA technology, forward and reverse sensing systems, and rear view camera technologies that were to be experienced in the evaluation was presented in the laboratory. The briefing was designed to ensure that participants were comfortable with the concepts behind the parking technologies and familiar with their basic operation. The briefing consisted of publically available short video clips prepared by the OEM explaining each technology. The videos were supplemented by pre-recorded narrative and pictures developed by the research group to reinforce key points from the manufacturer's promotional material and the vehicle owner's manual. Finally, participants were given portions of the vehicle owner's manual and encouraged to read the relevant sections describing the technologies.

Following the attachment and testing of physiological recording instrumentation, participants were escorted to the test vehicle. While approaching the vehicle, the rear ultrasonic sensors and rear view camera were pointed out such that the participant clearly understood their location on the vehicle. The participant was initially seated in the passenger seat and a research associate provided with a live demonstration of the operation of the three technologies as well as manual parallel parking of the vehicle. A second technology expectation questionnaire was then administered to capture the participants' reactions and expectations after having been extensively briefed on the technologies and seen an actual demonstration of the features. To ensure consistency between experimental sessions, the in-vehicle briefing material was primarily presented using audio recordings and supplemented by research associate comments and responses to questions only as needed.

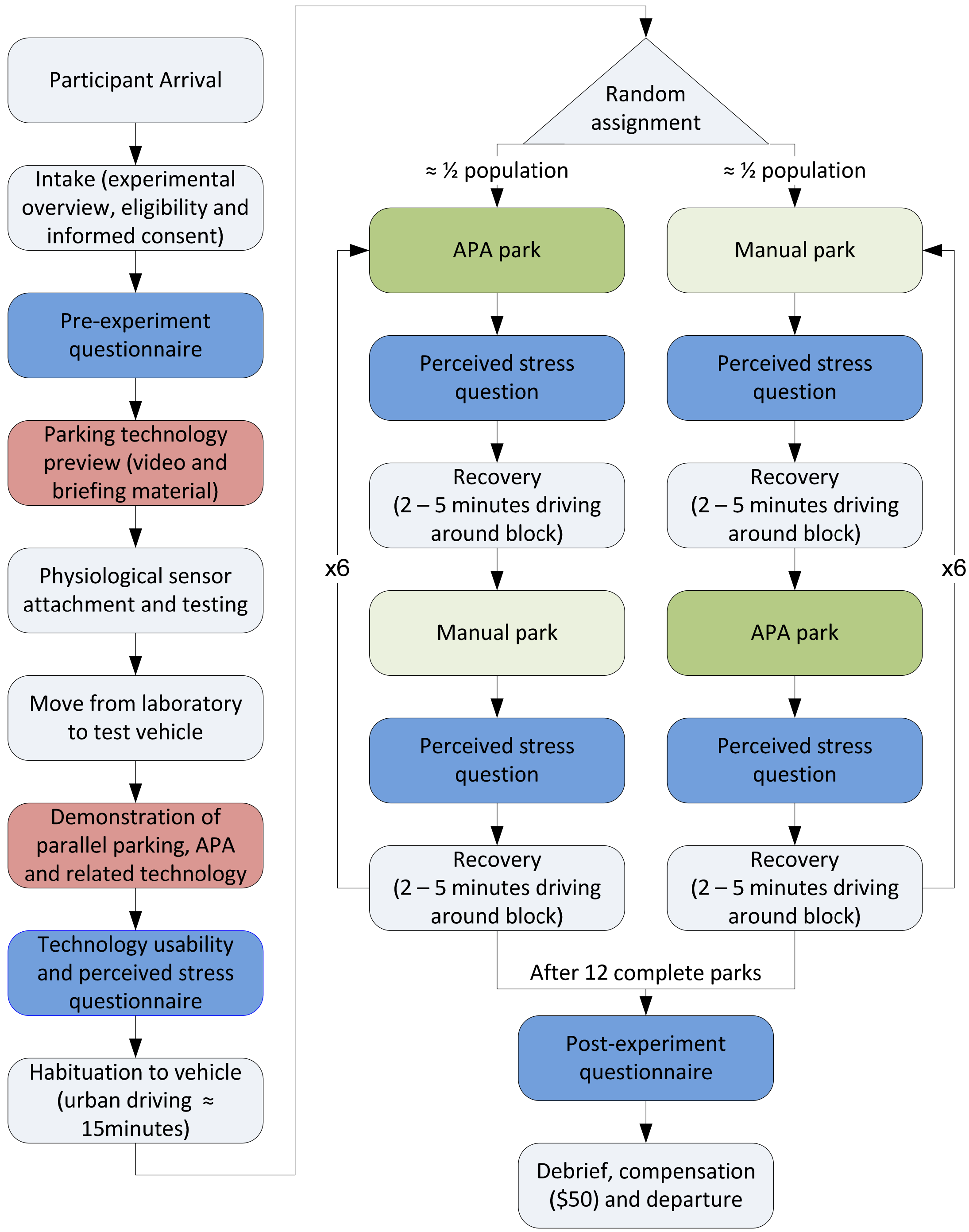


Figure 1: Protocol for Active Park Assist (APA) assessment with technology demonstration (red), self-report scales (blue) and parking assessment periods (light & dark green).

Parking trials were carried out on an urban street (Hayward St. Cambridge, MA) between two inflatable vehicles (balloon cars) spaced at a distance of 24 feet and positioned nine inches from the curb. Figure 2 illustrates the layout of the parallel parking space with the balloon cars. The vehicle shown parked in front of the first balloon car that was present throughout the experiment and was positioned immediately adjacent to a curb cut for a parking lot. This set-up ensured that the visual stimuli associated with identifying the parking location remained constant. As the test vehicle approached the designated parking location, the research associate pressed a key at a fixed point approximately a car length and a half prior to the front bumper of the vehicle entering the picture in figure 2. The key press placed a flag in the data file that was later used to mark the start of the analysis period. Other parking spots on the street were open for use to the public and were filled at certain various points during the experiment. No traffic control was present on the street, so participants' frequently needed to park with following traffic waiting or oncoming traffic passing as they would under typical driving conditions.

Figure 2: Experimental set-up for Active Park Assist™ (APA) assessment with balloon cars at either end of designated parking location.

A period of approximately 15 minutes of driving on local urban streets through a fixed route employing an extended series of turns was employed to develop familiarity with the basic maneuvering of the vehicle. As the participant returned to the parking location, they were provided with instructions indicating that they were to complete a series of practice parks. The instructions prompted them to either start parking with the APA technology or to park manually (half the sample was exposed first to an APA parking trial and half exposed first to a manual parking trial). Following this instruction, participants alternated parks between using APA and manually parking the vehicle. Following each park, participants were immediately asked "on a scale of 0 to 10 where 0 is not at all stressed and 10 is very stressed, how would you rate your stress level during the parking maneuver you just completed?" Verbal responses were manually recorded by the research associate.

Participants were then instructed to drive around the block and, depending upon what phase in the rotation they were in, approached the parking space and either parked manually or using the active park assist feature. A short reminder indicating whether the upcoming park was to be completed manually or with APA was played just before they turned onto the street with the designated parking spot. During the practice period, participants were free to ask the research associated questions about the operation of the technology. At the completion of the training trials (six parks), participates were briefed that "Each trial will consist of driving around the block, returning to the parking spot, parking the car and placing the car in park." Participants were instructed to continue alternating parking with and without APA and asked to verbally rate their stress level following each park. During the course of the experiment, heart rate data and vehicle telemetry was continuously recorded.

At the completion of the evaluation trials, a post-experimental questionnaire was administered to collect self-report data on the participant's current state, evaluation of the technologies, ranking of various aspects of the technologies, as well as providing several open-ended questions to allow them to comment on the technologies and share other insights or suggestions.

Procedure: Experiment 2 – Cross Traffic Alert™ (CTA)

Consistent with the first experiment, sessions for experiment 2 began in the laboratory with intake, the same pre-experimental questionnaire and a technology briefing along the lines of the one developed for the APA but focused on the Cross Traffic Alert™ (CTA) system. A number of other elements of the design were similar, as detailed in figure 3; however there were some notable differences. First, the entire in-vehicle portion of the experiment took place in an enclosed (underground) parking garage and required only limited maneuvering of the vehicle. This location was selected in part because we were able to maintain complete control over actual traffic flow relative to the test vehicle. The basic procedure consisted essentially of a series of parking events involving backing out of a front-in parking space, pausing and pulling forward back into the parking spot. The primary difference between trials was whether they were conducted with the CTA technology active or inactive. Since the requirement for familiarity with maneuvering of the vehicle was fairly limited, the extensive familiarization/habituation drive through the local community employed in the first study was not included. Instead, participants were walked through a series of practice parks to experience the operation of the reverse sensing system, rear view camera and CTA technology. These parks highlighted in red (figure 4 – next page) provided the participants with a familiarity with the various procedures and experiences they would encounter during the experimental portion of the protocol.

Figure 3: Experimental set-up in a parking garage for the Cross Traffic Alert (CTA) evaluation with a mid-sized car directly adjacent to Lincoln MKS test vehicle and then a white screen with the dimensions of a panel truck further obscuring the research subject's view. The confederate vehicle used to set-off the CTA warning can be seen in the background along with the rear of a balloon car at the right.

A design challenge for evaluating the potential stress reduction capabilities of the CTA system was to create a relatively realistic situation where participants experienced some of the uncertainty associated with potentially encountering a vehicle that they may not be able to see when backing out of a parking space. As shown in Figure 3, the experimental set-up had the test vehicle oriented in a front-in parking configuration. Participants were informed that there would be trials when they were backing up when a vehicle driven by a research associate would approach their location from the passenger side. On the passenger side of the experimental vehicle was a large concrete pillar, a mid-sized vehicle in the adjacent parking spot and then a screen built to the dimensions of a panel truck further obstructing the research subject's view. The experimental setup was configured so that the participants' view of the approaching vehicle was obstructed until they had backed up a few feet and their line of sight cleared the pillar on the right and extended sufficiently into the travel lane.

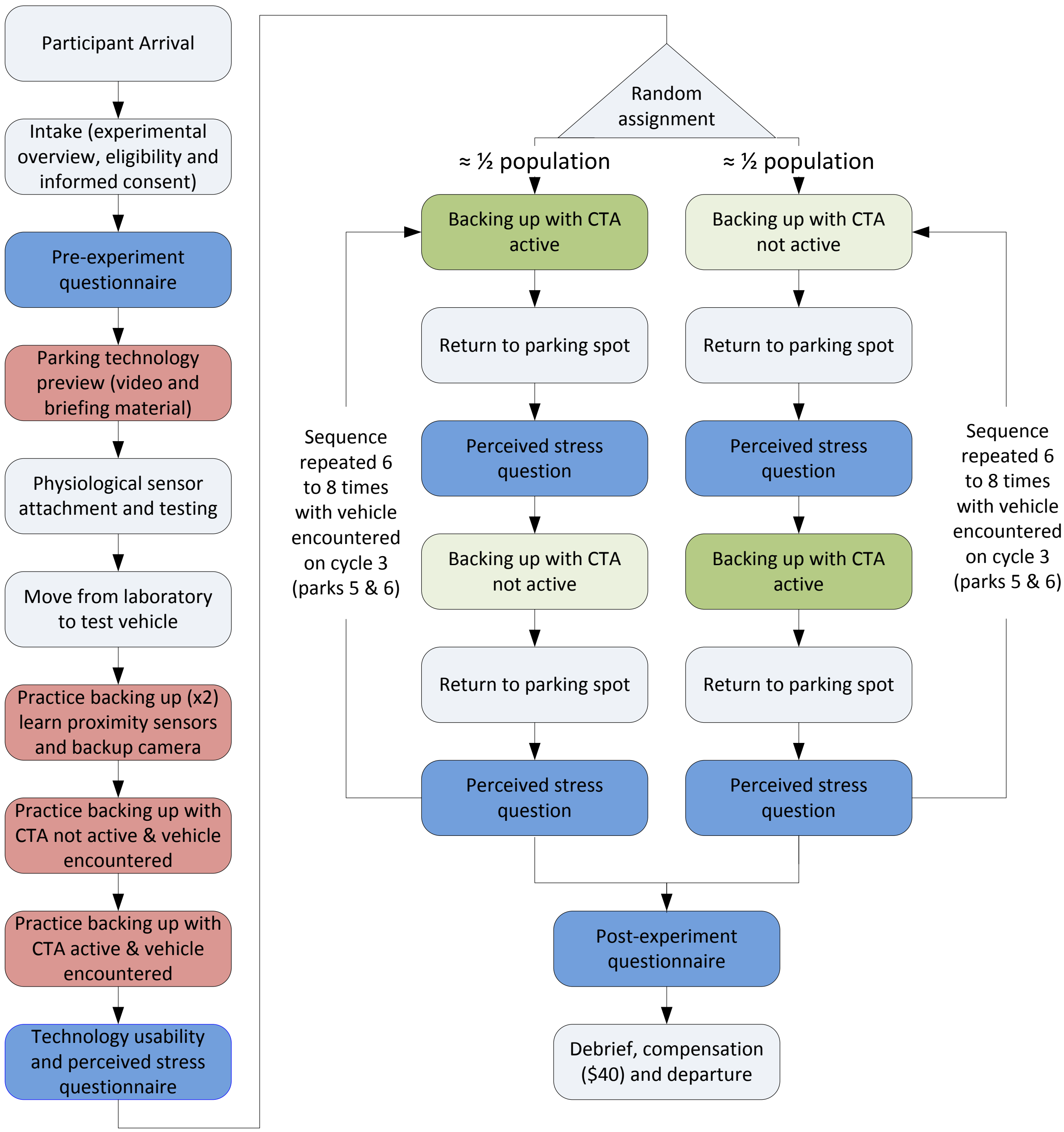


Figure 4: Protocol for Cross Traffic Alert (CTA) assessment with technology demonstration (red), self-report scales (blue) and backup assessment periods (light & dark green).

As indicated in the flow chart in figure 4, participants were told beforehand in practice back-up trials that when they would encounter a vehicle approaching as they backed out. The alerting technology was respectively off and then on for those trials. This was intended to give them experience with the extent to which it might be difficult to see an approaching vehicle and give them exposure to how the warning technology could assist in alerting them to the presence of an approaching vehicle. The following guidance was given drivers during the practice with the CTA turned off:

> *"When you are backing out of the parking space, please use any combination of looking over your shoulder, using the rearview mirror, the side mirrors, and the rear view camera that feels most comfortable to you. The decision to use any of these assistive devices is up to you."*
>
> *"We now want to show you how at certain points during the experiment a vehicle may approach you as you back up. If you do become aware of a vehicle approaching, bring this car to a stop by calmly stepping on the brake, just as you might be likely to do under normal circumstances."*

While the participants backed out of the parking space, the confederate vehicle approached the test vehicle as if this was a normal cross traffic encounter. For safety considerations, the confederate vehicle stopped at a fixed point regardless of the actions of the test vehicle. This represented a balance between creating a sense of risk versus unduly alarming participants. At the completion of this encounter, the recording instructions noted, "*…as you can see, the vehicle approached us but did not cross our path of travel. When you are ready, please pull forward in to the parking spot…".*

The following guidance was given drivers during the practice with the CTA turned on:

> *"Once again, when you are backing out of the parking space, please use any combination of looking over your shoulder, using the rearview mirror, the side mirrors, and the rear view camera that feels most comfortable to you. The decision to use any of these assistive devices is up to you."*
>
> *"Ok, let's now experience what happens when a car approaches with the cross traffic warning system active. When you are backing out of the parking space, if you hear the cross-traffic alert tone, notice the cross traffic alert light in the side mirrors, see an alert in the message center, or see the vehicle approaching as you are checking your surroundings, please calmly press the brake and come to a stop as you might normally do."*

At the completion of this encounter, the recorded instructions stated, "*…as you can see, as the vehicle approached us an alarm sounded and you may have noticed the warning light in the side mirror and/or the warning text in the message center. When you are ready, please pull forward in to the parking spot…".*

After the participant returned to the parking spot and verbally rated their current stress level, the second questionnaire was administered. The following instructions provided the expectation condition for the rest of the experiment:

> *"Now that you have had some experience with backing up the vehicle, and seeing what happens with and without the cross traffic alert active, we would like you to take the car through a series of alternating manual and assisted parking trials. Each trial will consist of turning the cross traffic alert on or off, backing out of the parking spot and returning to the parking spot. You will be prompted at*

> *each trial to either turn on or off the cross traffic alert, so you don't have to worry about keeping track of what to do next. During the alternating trials, you may experience a car approaching you. After each park you will be asked to rate your stress level. During the experiment you may be asked to complete as many as 20 complete backups."*

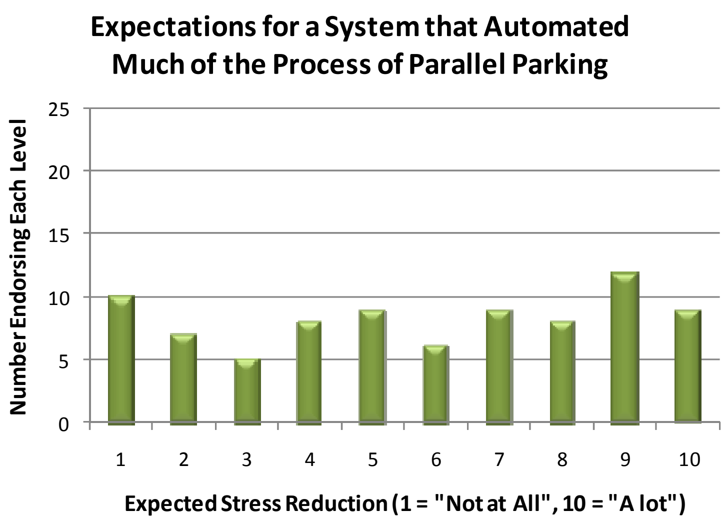
The design intent at this point was to create a realistic expectation that one or more vehicle encounters would occur over the course of the remaining backup trials. Half of the participants then began with a technology on trial and half with a technology off trial with all subsequent trials alternating the technology state. After four backups without encountering a vehicle, the confederate vehicle then again approached for the next two trials so that the participant again experienced one trial with the technology active and an approaching vehicle and one trial with the technology off and an approaching vehicle. An addition series of at least three trials each of technology on and off without an approaching vehicle were presented. It was expected that following their previous experience with an actual vehicle approaching as they backed up, there would now be a realistic expectation that additional encounters of this type would occur. As in experiment 1, participants verbally rated their current stress level at the completion of each backup trial and a post-experimental questionnaire was administered to collect self-report data on the participant's current state, evaluation of the technologies, ranking of various aspects of the technologies, as well as providing open-ended questions to allow for comment on the technologies and any other observations they wished to make.

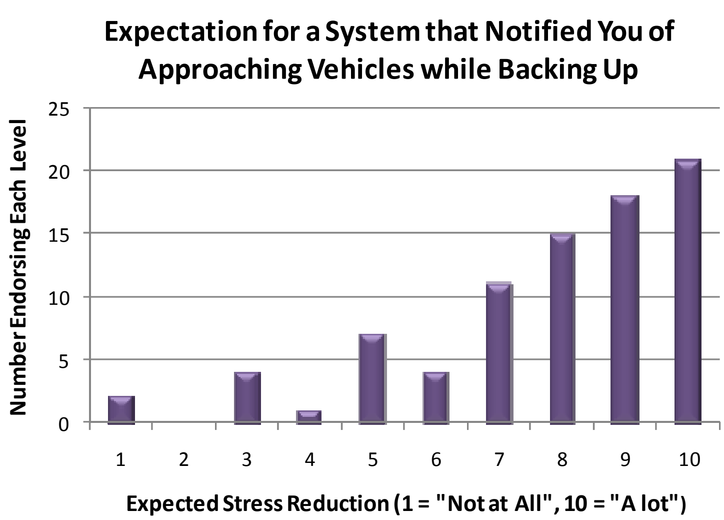
Data Reduction & Analysis

Heart beats were detected using *EKG Wave Editor* release 1.8 (NeuroDyne Medical Corporation, Cambridge, MA), a software package that identifies R-wave peaks in the raw EKG signal and provides editing functionality. Processed records were reviewed by trained research associates to identify and resolve any detection issues due to recording artifact and skipped and double beats were edited to provide a normalized heart rate record (Mulder, 1992). Unless otherwise noted, all statistical tests were carried out using a general linear model repeated measures analysis (SPSS 16.0). The standard criterion of $p < 0.05$ was used in determining statistical significance.

RESULTS

Expectations Prior to Exposure to the Technologies - A total of 84 participants are considered in this analysis. Individuals in both experiments completed the same pre-experimental questionnaire so that their expectations related to the two technologies prior to learning about them in-depth and actually working with the technologies could be assessed. A number of interesting observations can be made from the pre-experimental questionnaire data. Participants were asked to rate how comfortable they feel when parallel parking and when backing out of a parking space in a parking lot or a parking garage when their view is restricted. Using a ten point rating scale where 1 corresponded to "Very Uncomfortable" and 10 to "Very Comfortable", the mean comfort rating for parallel parking was 7.92 (SD 2.1), which suggests a fairly high degree of comfort. For backing out of a parking space with a restricted view, the mean comfort rating was somewhat lower at 6.94 (SD 2.3). Participants then rated the degree to which they felt that a vehicle system that automated much of the process of parallel parking would reduce their stress when parking. This was followed by a question that asked if they felt that a vehicle system that notified them of when vehicles were approaching from the side as they backed out of a parking space would reduce their stress when parking. These two stress questions again used a ten point scale where, in this case, the degree of expected stress reduction was scaled where 1 corresponded to “Not at All” and 10 corresponded to “A Lot” (figures 5 & 6 below). Participants gave a slightly positive but modest ranking of 5.75 (SD 3.0) for the expectation that a semi-automated parallel parking system would reduce their stress. In contrast, the mean ranking for the expected stress reduction of a cross traffic warning notice was markedly higher at 7.78 (SD 2.2).





Figures 5 & 6: Pre-experience expectations of participants regarding the extent to which an assistive parallel parking system (top graph) or a cross traffic warning system for use when backing up (bottom graph) would reduce stress levels. Stress rankings are on a 1 (“Not at All”) to 10 (“A Lot”) scale. Rankings for a parallel parking system were fairly evenly distributed across the range with a mean of 5.75. Expectations for a backup warning system were clearly higher, grouping at the positive end of the range and showing a mean value of 7.78.

The final four questions in the pre-experimental questionnaire explored the extent to which participants felt they would be likely to use such systems and whether such systems would influence their likelihood of purchasing a vehicle. The responses again suggested greater expectations for an approaching traffic warning system than for a parallel parking assistance system. In rating how likely it was that they would use such as system if it was in a vehicle (1 = “Not at All Likely”, 10 = “Very Likely”), a parallel parking assistance system was given a rating of 5.8 (SD 2.9) versus 7.95 (SD 2.4) for traffic warning system. In terms of impacting their interest in purchasing a vehicle (1 = “Not more Interested”, 10 = “More Interested”), the mean rating for an assisted parallel parking technology was 5.48 (SD = 3.2) while a traffic warning system for backing out of a parking space was again given a higher rating at 7.2 (SD 3.1). Taken together, all of these ratings suggest a higher interest in and expectations for a backup warning system relative to an assistive parallel parking system. As is detailed below, these expectations went through a clear changes over the course of the experiment in participants who had the opportunity to learn more about and experience each system.

Experiment 1 – Active Park Assist (Parallel Parking)

Subjects - The analysis sample for Experiment 1 consists of 42 subjects, half male and half female, equally distributed across three age groups (20’s, 40’s and 60’s). The age range for the 20’s group was 20 to 29 with a mean of 23.2 (SD 3.2), 41 to 48 for the 40’s group with a mean of 45.1 (SD 2.3), and 60 to 68 for the 60’s group with a mean of 65.4 (SD 2.4).

Objective Measures & Analysis Periods – As described in the methods section, all participants were exposed to a minimum of twelve parallel parking maneuvers, alternating between trials where the APA technology was active and trials where they engaged in standard manual parking maneuvers. The initial trials were designated as training exposure and the final six (three with technology and three without) were used for assessment purposes. Heart rate data was examined for three time intervals. The first interval was 10 seconds in duration and began when the test vehicle was approximately 75 feet from the designated parking spot. This was a period during which the driver was approaching the parking spot and was aware of whether they would be undertaking a manual parallel parking procedure or whether the APA system would active to assist them. This period was used to provide a measure of the participants’ anticipatory stress level. The second interval extended from the end of the 10 second anticipatory period through the completion of the parking maneuver; the duration of this period varied depending on how long it took the driver to carry out the parking maneuver. The final interval covered the immediate recovery period following the completion of the maneuver and extending for 25 seconds; this was the same interval during which the driver was prompted to verbally rate their stress level on a 0 to 10 scale.

A statistical model can be constructed that considers each of the three time intervals (immediately before, during, and immediately after parallel parking) and the two types of parking (assisted and manual) simultaneously. In this instance, both a main effect of time period ($F(2, 82)= 16.86$, $p < .001$) and a main effect of type of parking ($F(1, 41)= 126.94$, $p < .001$) are observed and the mean values for each of cells are presented in figure 7. While it can be simply stated than mean heart rate across the periods was significantly higher in the manual parking trails compared to the APA assisted trials (78.5 versus 71.7 beats per minute), the results are probably best understood by considering each of the three time periods separately.

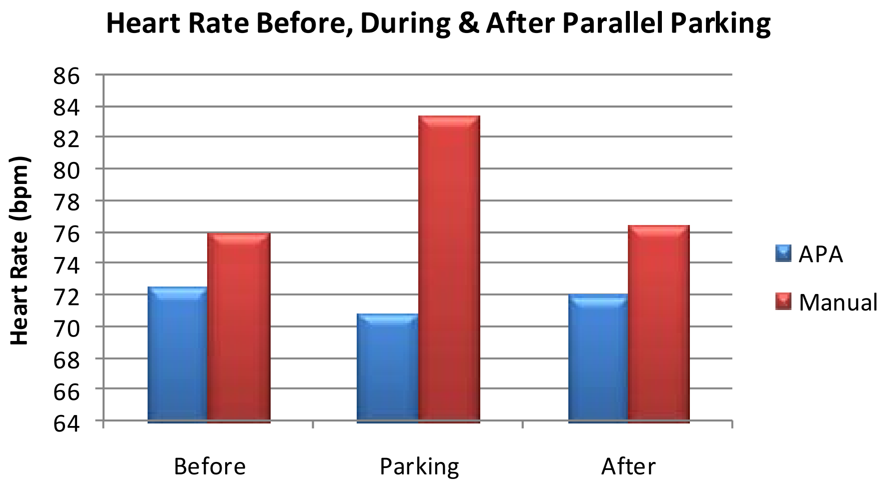


Figure 7: Mean heart rate values for 10 seconds prior to the parking maneuver, during the parking maneuver, and for 25 seconds following for both Active Park Assist (APA) and manual parking trials.

During the evaluation parking maneuvers, the average heart rate for participants when manually parking the vehicle was 83.3 beats per minute (bpm) (SD 12.8). When using the Active Park Assist (APA) system, average heart rate for participants was 70.8 (SD 11.8) – an average of over 12 bpm lower. To the extent that heart rate is considered an objective measure of effort or stress, parking with the APA system required markedly less effort and involved less stress. This difference in heart rate between the manual and assisted parking maneuvers was highly significant both practically and statistically ($F(1, 41)= 137.5$, $p < .001$).

This effect carried over into the period immediately following completion of the parking maneuver. Average heart rate in the period following completion of the manual parks was 76.4 bpm. Following the parks done using the APA system, average heart rate was 72.0, or 4.4 bpm lower. This difference was also highly significant ($F(1, 41)= 34.1$, $p < .001$).

While the more than 12 bpm higher average heart rate during the manual parks is the most dramatic finding in the analysis, the data from the initial 10 second anticipatory period prior to initiating the functional maneuvering of parking is in some ways even more interesting. During that period there was a moderate but highly significant difference in heart rate depending on whether the driver was about to use APA or to park manually. During the evaluation trials when drivers were anticipating engaging in a manual park, mean heart rate was 75.9 (SD 11.8). During the evaluation trials when drivers were anticipating parking using APA, heart rate was 72.5 (SD 12.4) or 3.4 bpm lower. This difference was highly significant statistically ($F(1, 41)= 56.89$, $p < .001$). This indicates that prior to the physical work involved in maneuvering the steering wheel to manually park, the anticipation alone associated with the upcoming parking task was more stressful then when drivers were anticipating parking with APA. This finding is particularly notable in that it is observed in individuals who had only had the opportunity to develop experience and trust in this technology for a relatively limited period of time.

Looking at the question of a learning and adaptation a little more closely, heart rate across each of the six parks during the anticipation period was analyzed in a repeated measures analysis. The effect of the repetitions was not significant ($F(2, 82)= 0.77$, $p = .468$) or interact with parking type (manual or APA) ($F(2, 82)= 1.91$, $p = .157$). This suggests that the difference in anticipatory arousal associated with assisted and manual parking was relatively well established at the point the formal evaluation trials were conducted. It may be a worthwhile investment of additional resources to process the heart rate data for the training period to evaluate the extent to which this difference in anticipatory arousal was present when participants first experienced the APA technology or if there was a very rapid adaptation to the technology over the course of the practice trials.

Subjective Evaluations (APA) - As noted in the previous section, participants verbally responded to the question "how would you rate your stress level right now?" immediately following the parking maneuvers using a 0 to 10 scale where 0 corresponded to "Not at all Stressed" and 10 corresponded to "Very Stressed". These verbal ratings averaged 2.6 following the manual parks and were lower at 2.0 following the assisted parks. This difference was statistically significant ($F(1, 41)= 5.16$, $p = .028$). As a comparison, the mean 0 to 10 rating provided by participants to this same question on the post-experimental questionnaire was 1.81 (SD 2.05).

At the end of the experiment, participants were given a questionnaire covering a wide range questions about their feelings and experience during the experiment as well as being provided with ample opportunity to comment in an open ended format. Several questions were selected prior to the initiation of the experiment as primary evaluation questions. These included questionings 3 & 4 which asked participants to rate respectively "how stressful was it parallel parking the vehicle manually?" and "using the assisted parking system?". The rating was on a 10 point Likert scale where 1 was "Not at All Stressful" and 10 was "Very Stressful". The mean rating for manual parking was 3.64 (SD 2.05), while the mean rating for using the APA system was significantly lower at 2.76 (SD 1.81), ($F(1, 41)= 5.8$, $p = .021$). This lower post experimental stress rating for parks using the APA system is in line with the verbal self-reported ratings that participants made immediately after each parking trial.

Overall ratings of the APA system were generally positive. In addition to using 10 point rating scales, some questions provided five categorical choices in the general form of "much easier", "somewhat easier", "no difference", "somewhat harder", "much harder", or similarly "much less stressful" through "much more stressful". In response to question 6 which asked "Do you feel that the assisted parallel parking system you used today makes it easier to park?", 76.2% rated it as making it easier to park, although 9.5% indicated that it made it somewhat harder. Similarly, in response to question 5 which asked "If you had a vehicle with the assistive technology you used today, how do you feel it would affect your stress level when parking?", 71.4% indicated that they felt the technology would decrease their stress level while parking while 14.3% gave ratings indicating they felt it would make parking more stressful. A detailed analysis of the characteristics and additional comments of the modest percentage of participants who did not appear to responds positively to the technology is clearly warranted.

Other items of particular note include question 8 which had participants rate how likely they would be to use the technology if it was in a vehicle they were driving. On a 1 to 10 scale (1= Not at All Likely; 10= Very Likely), the mean rating was 7.49 which represents a fairly high endorsement. When asked how likely is it that the technology would extend the range of conditions under which they would parallel park, the mean rating of 6.22 was also in the more likely direction of the scale. The most positive endorsement was a mean rating of 8.12 to the question that asked, "If you had a friend or family member who has some difficulty parallel parking or experiences some stress around parallel parking, would you encourage them to consider getting a vehicle equipped with the technology you experienced today?". It is interesting to observe that when asking participants to image themselves as an older driver who might need some assistance (i.e. "Imagining yourself as an older driver, do you think this technology has the potential to extend the time that you might confidently and safely operate a car?"), a more modest mean rating of 7.0 was obtained.

Change in Expectations (APA) – As detailed in the earlier section on pre-experimental expectations, participants expressed only modest interest in and expectations for the stress reducing capabilities of an assisted parallel parking system. After gaining experience actually using the system, their feelings concerning the system appear to have undergone a meaningful change. Considering the 42 participants in Experiment 1, while the mean rating for the likelihood that participants would use the technology if it was in a vehicle they were driving was somewhat neutral at 5.73 (SD 3.0) on a ten point scale prior to the experiment, it increased to 7.49 after the experiment. Similarly, when asked if availability of this technology would influence their interest in buying a vehicle, the pre-experimental rating of 5.15 (SD 3.4) increased to 6.48 after their experience with the system. It is clear in the case of the APA assessment that having a positive experience (reduced stress) when using the technology had the effect of moving their interest in and expectations for the technology into a more positive direction.

Age & Gender – The main findings on the objective and subjective stress measures presented above were consistent across the age and gender groupings, i.e. there were not statistically significant differences on these variables based on age and gender in the subjects recruited for this study. A more in-depth analysis considering possible moderator variables interacting with these demographic characteristics has not yet been undertaken.

Characteristics of the Park - As one estimate of the quality of the actual parking events, the average of the distance from the curb of the front and rear wheels was calculated. The average distance out from the curb for manual parks was 6.8 inches (SD 3.5). The average distance for assisted parks was markedly closer at 4.2 inches (SD 1.9). This difference was statistically significant ($F(1, 41)= 22.59$, $p < .001$). To the extent that consistency and distance out from the curve can be considered a useful index of parking quality, the assisted parks can be rated as comparable or even superior to the average manual park on this dimension. Data on more detailed driving behavior characteristics drawn from CAN bus recordings are available for future evaluation.

Experiment 2 – Cross Traffic Alert™ (CTA)

Subjects - The analysis sample for Experiment 2 consists of 42 subjects, half male and half female, equally distributed across three age groups (20's, 40's and 60's). The age range for the 20's group was 25 to 28 with a mean of 26.1 (SD 1.2), 40 to 48 for the 40's group with a mean of 44.0 (SD 2.9), and 61 to 68 for the 60's group with a mean of 63.9 (SD 2.4).

Objective Measures & Analysis Periods – As described in the methods section, participants were introduced to the technology through a series of practice trials that included encountering a vehicle while backing up, first with the CTA technology inactive and then with it active. Participants were then exposed to a minimum of twelve evaluation back up maneuvers, alternating between trials where the CTA was active and trials where it was not active. The first four trials were conceived of as anticipatory stress evaluation periods since participants had been informed that they would encounter an approaching vehicle one or more additional times during the experiment but no vehicle approached during these four trials. In the fifth and sixth trials (one with technology and one without), drivers encountered an approaching vehicle as they backed up. Data from this fifth trial is considered in the analysis as a between subject measure since half the subjects encountered the vehicle with the CTA technology active and half when the technology was inactive. Following the two evaluation trials with an approaching vehicle, drivers continued to alternate between parking with the CTA system on and off for at least another six parking maneuvers (three with CTA technology and three without CTA technology). If a false alarm was encountered, i.e. a CTA warning occurred when there was no approaching vehicle, up to four additional trials were run to provide a consecutive six park sequence without any technology issues for assessment purposes. In total, six subjects required extra trials to because of false alarms. In all but two of the six cases (two 60 year olds), a sequence of six parks occurred without a false alarm prior to park 16. For these latter two participants, measures for this interval were computed over the final four parks.

From the point that participants released the brake and began actively backing up the vehicle, backing up events were found to be relatively brief. The average time that the test vehicle was actually moving backward during the final three CTA active trials was 10.3 seconds and for CTA inactive trials was 7.1 seconds. Ideally, heart rate data should be collected over periods of about 10 seconds or longer to obtain an average that reasonably takes into account variation due to the respiratory cycle. The interval of recording selected for analysis consisted of five seconds prior to the vehicle coming to rest and five second following, providing a 10 second sample. This heart rate data was examined across three portions of the study. Data gathered from the first backup trial was used to provide an initial between subject measure of stress level based upon condition (with or without CTA technology). The second assessment period consisted of data drawn from the fifth evaluation backup where participants encountered the approaching vehicle for the first time during the formal evaluation phase of the experiment. This measurement provided a comparison between the stress levels of drivers who had CTA versus those who did not (i.e. half the sample had CTA active during evaluation trial 5 and half did not). Finally, as noted earlier, the third assessment interval considered a series of backing up trials following the exposure to an approaching vehicle.

During the initial evaluation trial, the average heart rate for participants backing up without CTA active was 78.7 bpm (SD 12.1). For individuals who experienced CTA being active during the first trial, the average heart rate was 75.9 (SD 10.0) – an average of 2.8 bpm lower. While the observed mean difference in heart rate is in a direction that is consistent with a reduction in arousal associated with the CTA technology, the distribution of heart rate values across the sample is sufficiently variable that this cannot be considered a statistically significant difference ($F(1, 40)= 0.67$, $p = .419$).

Looking at participants' first experience encountering an approaching vehicle during the evaluation period, all drivers who received a traffic alert warning from the CTA technology stopped and yielded to the approaching vehicle, while only 15 of the 21 drivers backing out without the aid of the technology appropriately stopped. This is notable since it bears on the potential safety benefits of the system. It is also appropriate to note that there was one case in which the CTA technology was active and the driver did not receive a warning as the vehicle approached. Among the 15 participants who did stop, the average heart rate of those not receiving a CTA alert was 73.8 (SD 11.7) while heart rate among the 20 drivers who received an alert was 71.4 (SD 9.6). The 2.4 beat differences in heart rate between the conditions is constant with the general trend towards lower mean arousal levels with the CTA technology; however, this difference was again not statistically significant ($F(1, 33)= 0.15$, $p = .505$).

As noted above, 6 out of the 21 drivers for whom the CTA warning system was not active during the evaluation encounter with the approaching vehicle, did not stop appropriately. In these six individuals, their mean heart rate of 82.3 (SD = 15.7) was 8.5 bpm higher than for those in the same condition who did stop, although, given the variability and size of the subsamples, this difference does not reach statistical significance ($F(1, 19) = 1.90$, $p = .184$). To the extent that this difference is not a chance finding, one speculation is that some of these individuals may have noticed the approaching vehicle at some point but were uncertain as to whether they should yield or not, resulting in greater physiological arousal. If this were the case, then one practical function of the CTA warning system might be to assist the driver by triggering a more reflexive defensive driving response as opposed to dealing with the uncertainty of deciding upon an appropriate course of active. Again, this is highly speculative but does suggest some interesting questions for future research.

Finally, looking at the composite measures of the three backup maneuvers completed with and without the CTA technology that followed the participants' experiences with approaching vehicles in evaluation trials 5 and 6, heart rate did not differ significantly by technology status ($F(2, 41)= 2.02$, $p = .163$). Heart rate across parks where the CTA system was not active was 73.6 (SD = 10.1) while it was nominally lower at 72.9 (SD = 10.4) during parks where the CTA technology was active. Interestingly, if participants who did not stop for one or more of the two trials with the approaching vehicles (n=7) and the individual who failed to receive an alert during a trial with APA active and the vehicle approaching are excluded from the analysis, the effect of technology on heart rate is statistically significant ($F(2, 33)= 6.30$, $p = .017$) with heart rate during trials without the CTA technology active being slightly higher at 72.4 (SD 8.6) compared to heart rate during trials with CTA active which was 71.2. Realistically, however, this difference is modest and is best considered suggestive given the various exclusions applied to obtain this value.

Subjective Evaluations (CTA) – While many of the subjective stress ratings were nominally in the direction of lower values when the CTA system was active, none of the comparisons considered was statistically significant. The mean verbal rating by participants of their stress levels following the first park was 1.6 (SD 1.7) in cases where warnings were not available and 1.4 (SD 1.5) when the system was active ($F(1, 40)= 0.14$, $p = .709$). The reported stress level in cases where a vehicle approached and the CTA system was not active was 2.1 (SD 1.9) while stress reported in cases where the participant received alerts was nominally but not significantly lower at 1.5 (SD 1.5) ($F(1, 33)= 1.11$, $p = .300$). Overall stress ratings across the final parks without the CTA technology and with it active, perceived stress levels were virtually equivalent at 0.90 (SD 1.17) and 0.87 (SD 1.16) respectively ($F(1, 41)= 0.29$, $p = .592$). Excluding cases where participants failed to stop or did not receive alerts where appropriate has no appreciable impact on the model.

As described in the results section for the parallel parking study, several questions in the post-experimental questionnaire were pre-designated as primary evaluation questions. In specific, questionings 3 & 4 asked participants to rate respectively "how stressful was it back out without the cross traffic alert system? and "with the cross traffic alert system?". The rating was on a 10 point Likert scale where 1 was "Not at All Stressful" and 10 was "Very Stressful". The mean rating for backing out of a parking space without the CTA technology was 2.31 (SD 1.76) and the mean rating when using the CTA system was lower at 1.98 (SD 1.33). While the lower rating for the CTA system was in the expected direction, the difference was not statistically significant ($F(1, 41)= 1.10$, $p = .300$).

Overall ratings of the CTA system and open ended responses were generally positive. In addition to using 10 point rating scales, some questions provided five categorical choices in the general form of "much safer", "somewhat safer", "no difference", "somewhat less safe", "much less safe", or similarly "much less stressful" through "much more stressful". In response to question 6 which asked "Do you feel that the cross traffic alert system you used today makes it safer to back out of a parking space?", 78.6% rated it as making it safer to backup while 4.8% reported that the system made it less safe. In response to question 5, which asked "If you had a vehicle with the cross traffic alert technology you used today, how do you feel it would affect your stress level when backing out of a parking space?", 66.7% said it would be less stressful while 14.3% said that it would be more stressful. Future research will need to examine if there is a relationship between false alarms, missed detections and the degree of positive endorsement of the technology.

Change in Expectations (CTA) – As described in the section on pre-experimental expectations, participants expressed an interest in and relatively high expectations for the stress reducing capabilities of a system that notified them of approaching vehicles when backing out of a parking space. After gaining experience using the system in the context of this experiment, their feelings concerning the system appear to have undergone a slight shift. Considering the 42 participants in Experiment 2 - While the mean rating for the likelihood that participants would use the technology if it was in a vehicle they were driving was quite high at 8.07 (SD 2.6) on a ten point scale prior to the experiment, it was somewhat lower at 7.69 (SD 2.9) after the experiment. Similarly, when asked if availability of this technology would influence their interest in buying a vehicle, the pre-experimental rating of 7.41 (SD

3.0) decreased somewhat to 6.86 (SD 2.4) after their experience in the parking garage scenario. It is important to note here that participants' exposure to the CTA technology may not have been as realistic a model of what their experiences would be under normal operating conditions as was the case with the APA assessment. This issue is considered in more detail in the discussion section of this report.

Putting aside for the moment the question of whether the APA and CTA experimental designs provided equally valid modeling of actual operating experiences, it is interesting to observe how participants' ratings of their likelihood of using the technologies and their relative interest in acquiring vehicles with the technology shifted on the basis of their experience. General interest in the parallel parking technology was only slightly over the mid-point of both scales prior to learning details of the technology and actually using it. Expectations for the CTA system were much higher. After exposure to the systems, rankings for the APA system shifted up markedly while those for the CTA system moderated somewhat. The net result was that both systems were ranked positively and at quite similar levels on these scales in the post-assessment questionnaires.

Age & Gender – Looking between technology conditions during the first park, the first park with an approaching vehicle and within participant scores for the final six parks, heart rate and perceived stress were not systematically impacted by age and gender groupings, i.e. there were not statistically significant differences on these variables based on age and gender in the subjects recruited for this study. The only statistically significant effect that appears is an interaction of age and gender on the perceived stress ratings for the final parks. A more in-depth analysis that includes a consideration of possible moderator variables interacting with these demographic characteristics has not yet been undertaken.

Technology Performance - It is important to note that a number of false alarms were observed, i.e. conditions where the CTA technology provided an alert where it should theoretically have not occurred. Considering both the practice and evaluation trials, drivers using the CTA technology received a false alarm in 5.2% of the trials. This corresponded to 42 false alarms across the 400 backup maneuvers and sixteen of the 42 participants experiencing this condition. In addition to the miss detection noted previously, during the demonstration portion of the session two other participants experienced missed detections, one of them twice. It is difficult to gauge if these issues were the result of the experimental setup, driver behavior, etc. since the study was not designed to explore these questions.

DISCUSSION

The results for the first experiment are in line with the hypothesis that use of the semi-automated parallel parking assistance system resulted in reduced stress levels in the participants both on the basis of objective physiological data and self-reported stress levels. The greater than 12 beat per minute difference in heart rate between manual parking and parking with the APA system is particularly striking. Also significant is the finding that heightened arousal is associated with the anticipation of manual versus assisted parking. The pattern of findings for these primary measures is consistent across gender and the age groupings in the population assessed in this study.

Given that the heart rate data as well as a wide range of immediate verbal and post-experimental questionnaire responses all support the assessment that the assistive technology made parallel parking easier and less stressful for most participants, it is of interest to observe that the physiological measure provided the most robust statistical case for the effective difference between the two modes of parking. This suggests that, at least in some situations, that physiological measures can be more sensitive than standard self-report methodologies for making such distinctions. Making this point does not imply an endorsement for dispensing with detailed questioning of participants about their feelings, reactions and experience with the systems under evaluation. These types of data provide important detail and characterization that can contribute significantly in interpreting and better understanding the meaning of the observed pattern of physiological results.

The data from the cross traffic warning system study produced a less clear evaluation. Mean self-report and heart rate data were suggestive of some reduction in stress levels when the CTA system was active, although these differences tended to be small and most were not found to be statistically significant. The most significant finding was the observation that drivers were more likely to appropriately stop and yield to an approaching vehicle during trials when the cross traffic alert system was active. This appears meaningful in that it suggests possibility that a reduction in accidents when backing up the vehicle could be the effective result. To the extent that this is the case, then the CTA system will certainly be likely to have an effect and the stress associated with actually having a close call or actual accident as a result of not noticing an approaching vehicle with sufficient warning.

One of the reasons for the limited differences in heart rate and self-reported stress levels between the technology active and inactive states in the CTA study may have to do with certain aspects of the experimental design as well as the nature of how the technologies are experienced. In the case of our assessment of the assistive parallel parking system, drivers were clearly aware of when they were engaged in a trial of manually parking the car versus when they were using the APA system. In contrast, debriefing discussions with the research associates who sat in the vehicle with participants revealed that a number of drivers made comments suggesting that they were uncertain during some trials as to whether the CTA technology was active or not. This occurred in spite of the fact that participants actually carried-out the multistep process of turning the technology on or off at the start of each backup trial. None the less, this highlights one of the ways in which developing a sense of the functioning of a warning technology such as the CTA system has some fundamentally different characteristics than developing experience with a system like the assistive parallel parking technology. In the case of experiencing parking with and without APA, drivers are very clear about when the technology is active or not. Consequently it is easy to actively attend to how the technology is functioning and to form impressions about whether it meets expectations, is helpful, etc. In the case of a warning technology like CTA, it is not always obvious to the driver when the technology is actively doing something for them since it is only overtly present when a warning is activated. This suggests that the alternating exposure protocol that worked well for assessing the APA system was not optimal in the case of CTA. Based on this experience, alternate designs such as experiencing the technology states in separate blocks with a break in-between might provide a better model or with entirely separate sets of participants (although the latter approach would require a larger research sample than the within subject design to appropriately deal with individual variability).

Another factor in the CTA assessment is the issue of false alarms and missed alarms. Although the absolute number of such events was not high, the fact that a number of participants experienced them is likely to have contributed to some uncertainty on their part as to the functional characteristics of the system and the degree of trust to be placed in the system. This presents one of the significant challenges of developing hazard detection and warning systems. For the type of warning system being considered here, a requirement that the system work with 100% accuracy is most likely an unrealistic design goal and would mean that such a warning technology would never leave the development laboratory. If such systems were never released, then the potential benefits of cases where the driver would have otherwise not noticed an approaching vehicle would not be obtained. Clearly there is an important balance here between realistic system function and a false detection and failure of detection rate that most users will find acceptable and in which they will develop realistic trust. This continues to be an area where additional research is desirable. The fact that the CTA system did, in a limited number of instances, fail to detect the approaching vehicle reinforces the manufacturer's instructions to users that the system is intended as an aid and does not replace the driver's responsibility to use their mirrors and other appropriate methods of maintaining awareness of their surroundings. Assistive technologies offer the potential to increase safety and comfort as well as decrease workload and stress, but they do not remove the reality that the driver is still responsible for overall operation of the vehicle.

Research continues to address the use of physiological measures and visual perception indices as sensitive indicators of driver workload, arousal and stress when operating a vehicle with different assistive and safety technologies. As discussed earlier, use of these sensitive assessment methodologies during the design and development process should aid manufacturers in selecting optimized designs with the least demand on the driver, resulting in greater user satisfaction, increased safety, and enhanced well being. The broader integration of sensitive measures of driver state will hopefully one day provide the foundation for adaptive features to alert or calm the driver as has been proposed in the AwareCar concept.

Notes: Active Park Assist™ and Cross Traffic Alert™ are registered trademarks of Ford Motor Company.

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About MIT

The Massachusetts Institute of Technology, a co-educational privately endowed research university, is dedicated to advancing knowledge and educating students in science, technology, and other areas of scholarship to serve the nation and world. The Institute has more than 900 faculty and 10,000 undergraduate and graduate students. MIT's commitment to innovation has led to a host of scientific breakthroughs and technological advances. Achievements include the first chemical synthesis of penicillin and vitamin A, the development of inertial guidance systems, modern technologies for artificial limbs, and the magnetic core memory that led to the development of digital computers. Sixty-three alumni, faculty, researchers and staff have won the Nobel Prizes.

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The New England University Transportation Center is a research, education and technology transfer program sponsored by the US Department of Transportation. Together the faculty, researchers and students sponsored by the New England Center conduct work in partnership with industry, state & local governments, foundations and other stakeholders to address the future transportation challenges of aging, new technologies and environmental change on the nation's transportation system. For more information about the New England University Transportation Center, visit utc.mit.edu. For more information about the US Department of Transportation's University Transportation Centers Program, please visit utc.dot.gov. The New England Center is based within MIT's Center for Transportation & Logistics, a world leader in supply chain management education and research. CTL has made significant contributions to transportation and supply chain logistics and helped numerous companies gain competitive advantage from its cutting edge research. For more information on CTL, visit ctl.mit.edu.

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The Massachusetts Institute of Technology AgeLab conducts research in human behavior and technology to develop new ideas to improve the quality of life of older people. Based within MIT's Engineering Systems Division and Center for Transportation & Logistics, the AgeLab has assembled a multidisciplinary team of researchers, as well as government and industry partners, to develop innovations that will invent how we will live, work and play tomorrow. For more information about AgeLab, visit agelab.mit.edu.