Journey: General Motors' Move to Incorporate Contextual Design Into Its Next Generation of Automotive HMI Designs

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ABSTRACT
This paper describes the first of five Contextual Design projects undertaken by the General Motors User Experience (UX) Design Team. The project, titled "Journey," focused on gaining a deeper understanding of how drivers interact with today's entertainment, communication, navigation, and information systems in their vehicles. In addition, we wanted to learn how drivers balanced interacting with these systems with the primary task of driving in situ. The results of this effort helped the General Motors team to concept and create the next generation of infotainment systems that support and extend these in-vehicle experiences, creating delight for customers of new GM vehicles. The first vehicles to include this new generation of driver-centered infotainment systems design are scheduled to be introduced in future model years. In addition, the team learned several valuable lessons about applying contextual research methods in an automotive environment.

Categories and Subject Descriptors
H.1.2 [**User/Machine Systems**]: Human Factors, Human Information Processing, and Software Psychology.

General Terms
Design, Human Factors.

Keywords
Contextual Design, Contextual Inquiry, Automotive HMI Design, Product Design Process.

1. INTRODUCTION
In 2001, General Motors formally began its journey into user-centered design of in-vehicle infotainment and telematics systems. Prior to that time, suppliers such as Delco Electronics and DENSO Corporation offered user interface designs for such systems based on a set of high-level requirements provided by GM (e.g., radio shall have an AM/FM tuner, cassette player, CD player, bass/midrange/treble adjustment, etc.). GM wanted to take over ownership of the user experience of these systems; which meant they now had to define in more detail what they wanted and how they wanted these systems to behave from the user perspective.

During the early years of adopting user-centered design, the design team relied heavily on the experience of individual team members during the concept and design phases and employed usability testing to iteratively refine the designs. This approach led to some success such as the 2008 Cadillac CTS, CNET Tech Car of the Year award winner [1]. However, the team recognized the need to develop a more formal design process that included a pre-conceptual user research phase to drive innovation in future system designs.

In 2008, the GM UX Design team adopted the Contextual Design process [2][3]. This paper describes the first of five Contextual Design projects that GM undertook following the Contextual Design methodology as outlined by Beyer and Holtzblatt [2]. The focus of this particular project was to gain a deeper understanding of how drivers interact with today's entertainment, communication, navigation, and information systems in their vehicles. More specifically, we wanted to:

- Document user intents for entertainment, communication, navigation, and information system usage.
- Study the balance between in-car systems and carried in devices usage.
- Determine how users' outside lives should be supported by in-car systems.
- Capture how in-car tasks interact with the driving task – "the dance" between hands, eyes, ears.
- Determine how individual differences in tolerance to sensory overload, mental models of navigation, and age affect these interactions.
- Uncover the values that customers have around brand, design and aesthetics.

In addition, the team learned valuable lessons for applying the Contextual Design research method in the automotive environment. The primary focus of this paper explains how GM adapted the Contextual Design methods for use in our vehicle Human-Machine Interface (HMI) design process. As a secondary focus, we identify lessons learned along the way and how what we learned affected product design. All this is described in the following sections.

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2. DESIGN PROCESS APPROACH

2.1 Contextual Design

The first phase of the Contextual Design process, as described in [2] and [3], was used by the design research team consisting of members from GM's UX Design team and InContext, the firm responsible for creating and improving the Contextual Design method. This part of the process consisted of a series of contextual inquiries, followed by interpretation sessions by team members. The team then took all the data collected and began to consolidate and model the data for use in the final steps of creating personas and visioning new concepts. The following describes each step in greater detail.

2.1.1 Contextual Inquiry

The team started by conducting contextual inquiry interviews while riding along with participants on their trips (see Trip Types below for details). Two person teams rode along with the driver and his/her passengers (e.g., kids, co-workers, etc.), if applicable. These interview teams were structured, when possible, to include both a male and female interviewer, such that female participants felt more at ease with the interview team in their vehicle. The lead interviewer rode along in the front passenger seat, guiding the inquiry to maintain focus on the key areas of interest for the design project. He or she recorded detailed notes regarding user interactions with systems in the vehicle, as well as inquired about user intents when interacting with these systems. They also recorded when breakdowns in interactions were observed.

Typically, a second team member was present in the back seat and recorded detailed notes about driver interactions with the various in-vehicle systems and brought-in devices. In addition, the second team member recorded driver hand locations and general glance-behavior; the context of these actions to the trip segment was also noted (e.g., if stopped at a light or intersection, if driving on a freeway or street, etc.). There were a few instances where only a single observer could ride along due to the configuration of the vehicle (e.g., two seats) or the number of passengers riding in the vehicle (e.g., a family returning from vacation or a carpool commuting to/from work). In these cases, the interviewer also utilized an audio recording device to assist in documenting the driver's comments.

Both team members sketched various aspects of the participants vehicle interior that were of interest and took pictures of key components or interactions of interest, where permitted (see Figure 1). In addition, the team captured notes and video using tablet PCs and web cameras to record detailed task sequences for later analysis.

2.1.2 Interpretation Sessions

Within 24 hours after each interview, the two-person interview team, along with members from the larger project team, conducted an interpretation session of that interview. An interpretation session consisted of retelling the entire interview and capturing key notes, breakdowns, insights, responsibilities, and any design ideas that may have come to mind. In addition, the team created sequence models and artifact models based on the observational notes, sketches/pictures, and videos. The travelling interview team would often link in members of the broader design team back in the home office using web conferencing software. This allowed the broader design team to gain a deeper understanding of the project data being collected, while minimizing project expenses by keeping a minimum number of people on the interview team at any one time.

The interpretation sessions with the larger team created a shared perspective of the data and allowed the team to characterize what really mattered to the drivers in the situations observed. In addition, by involving other members of the team who were not on the interview, they could ask questions about certain aspects of the interview to get at the user's real intents. This not only helped guide the focus of subsequent interviews, but it also helped uncover detail that may have been overlooked at the time because it seemed unimportant to the interviewer. By involving others, it also helped serve as a way to make the data 'real' to the rest of the team by reliving the entire experience along with the interviewers. The notes, sequence models, and artifact models from each interview formed the basis for the next phase of data consolidation and modeling.

2.1.3 Affinity Diagram and Work Models

During the middle of data collection, the team scheduled one week to perform an initial consolidation of data collected to date and begin the work modeling activities. The team started by taking the individual notes from the interpretation sessions and created an initial affinity diagram. The team also took the sequence and artifact models from the interpretation sessions and began to consolidate them into a single representation of work practice in the vehicle. This intermediary consolidation week allowed the team to identify open question areas in the data and to hone the project focus for the remainder of the field interviews.

At the end of data collection, the team had over 2500 notes from the 30 interpretation sessions. These notes were all arranged into a single, final affinity diagram that covered approximately 250 square feet of wall space (see Figure 2). The consolidated sequence model describing all the relevant tasks in step-by-step detail was over 35 feet long (see Figure 3). The consolidated artifact model captured, in detail, how drivers used the interior spaces of their vehicles, often in ways not originally designed for (see Figure 4).

Figure 1: Contextual Inquiry

Figure 2: Affinity Diagram

Figure 3: Consolidated Sequence Model

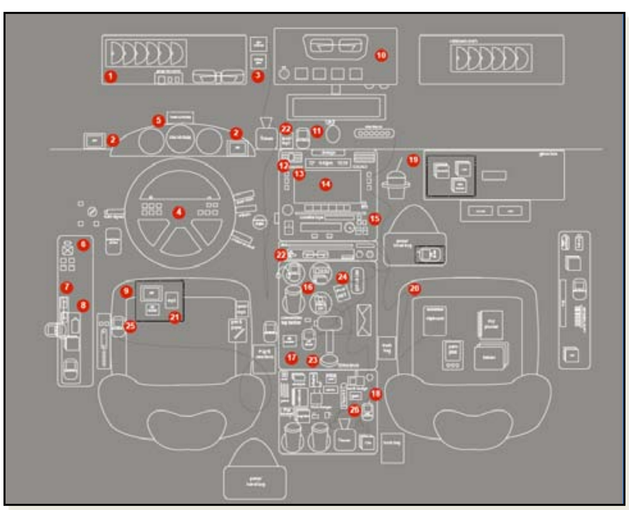

Figure 4: Consolidated Artifact Model

The data consolidation and work modeling phase ended with the creation of Personas [4][5]. The team created eight different Personas based on the data collected from the interviews, each representing a unique set of work practices and driver goals/needs/roles/responsibilities.

2.1.4 Visioning

The team finished the first phase of the project with "Visioning," a structured ideation/brainstorming process to imagine and develop new product concepts. The Visioning process began by walking the wall of data; that is, the Affinity Diagram, Consolidated Sequence Model, Consolidated Artifact Model, and Personas. While walking the wall, any design ideas that individuals came up with were written down and placed next to the issues they attempted to solve. Once the team had re-immersed themselves in the data, they began a "grounded brainstorm" [2] session by picking a Persona and a starting point to create a new reality of the vehicle, including its systems and how it supports the Persona's goals while driving. Design ideas that were documented during the interpretation sessions and wall walk were incorporated into the vision where appropriate.

Based on the data collected, the team created more than two dozen high-level concepts for next generation infotainment systems, which were whittled down through a review and voting process to approximately 15 ideas that were shared with senior leadership at General Motors. Over 150 design ideas were generated based on the visions and data, resulting in numerous records of invention submissions.

2.2 Participants

Thirty participants were interviewed for this project. Four locations in the United States were selected from where to recruit participants and conduct the interviews. These locations included:

- Boston, MA (6 participants);
- Atlanta, GA (8 participants);
- Chicago, IL (8 participants); and
- San Francisco, CA (8 participants)

Participants were recruited based on the type of vehicle they drove, either a "best"/luxury-type vehicle (e.g., Cadillac, BMW, Audi, Mercedes, Acura, Lexus, etc.) or a "good"/"better"-type vehicle (e.g., Buick, Chevrolet, Ford, Chrysler, Honda, Toyota, etc.). They were selected for participation based on their use of entertainment, communication, and/or navigation systems in their vehicles while driving.

The team tried to balance the male-to-female ratio as best as possible in the participants. The ages ranged from four in their late twenties up to one in his sixties. The average age was in the mid-thirties.

2.3 Trip Types

As part of the project goals, we wanted to understand how trip type may affect the use of entertainment, communication, navigation, and information systems in the vehicle. Therefore, we recruited participants based on several trip types to make sure we were not missing any key bits of information to aid in our design process. These trip types included:

- Commuting (7 participants)
- Sales / Work-related trips (7 participants)
- Running errands / shopping (7 participants)

- Weekend / long distance travel (4 participants)
- Urban driving (5 participants)

3. RESULTS

The affinity diagram exercise led the team to identify numerous challenges users face in their cars and with the technologies they use while in their cars. One key finding was that the participants' "lives" flow through and around their cars – they didn't stop at the close of the car door. The problem too often is that their car isolates them from this life. As of the date of this data collection, late-model vehicles did not do a very good job of supporting devices and data flow into and out of the vehicle. This was cause for frustration and the adoption of less socially desirable behaviors by drivers as evidenced in the second key finding.

The second key finding was that driving was too often the least important thing going on in the car. We are all familiar with the issues of distracted driving and the evidence supporting the need to address such distractions in evermore safer manners [6]. Participants in this study had many activities competing for their eyes, hands, ears, and brains. Some of the tasks competing for their attention included cell phone conversations, SMS and e-mail exchanges, navigation routing instructions, finding suitable entertainment to listen to, addressing the entertainment needs of others riding along in the vehicle, and getting information such as vehicle status, location-based information, traffic, weather, etc.

A third key finding was that navigation means more to users than just getting route instructions from point A to point B. In-vehicle navigation systems provide situation awareness, security, entertainment, and educational opportunities to the driver and vehicle occupants. In addition, the concept of navigation can start long before anyone enters the car, as we observed a great deal of trip planning was done online using the participants' personal computers. Breakdowns were often observed when users tried to transfer all their trip planning activities into the vehicle for use.

A fourth key finding was how complex and intimidating users found learning to use the technology in their vehicles. People had high expectations for extracting and using previous knowledge gained from prior vehicles and the consumer electronics world. Many new vehicles and their associated technologies failed to support this existing knowledge. Often times, users had not read the user manual or the manual was insufficient to support them in accomplishing their goal(s). This finding alone led to a separate Contextual Design project, which we will report on in the future.

A fifth key finding was that buyers of luxury vehicles (i.e., the "best" vehicles as defined in our study) expect a lot from a luxury brand experience. Participants driving luxury vehicles had no tolerance for difficulty of use or the sharing of "common look" components with lower tier vehicles from the same manufacturer. These individuals are savvy consumers and can recognize part re-use across an Original Equipment Manufacturer's (OEM) brands; for example, sharing cheap window switches or infotainment systems from lower-class brands offered by the OEM in their luxury brands. Buyers in the luxury brand segment want to be part of an exclusive club and be treated as such – it's not just the car, but an experience.

A main take-away for the GM design team was that by removing the barriers in and around the car and addressing the driver distractions associated with the integration of technologies required to support the user's life in the vehicle, GM could change the game for the next generation of infotainment and telematics system designs with respect to interaction design and user experience.

A challenge the team was confronted with when reporting the results back to its management was the question of whether or not any real design decisions could be made based solely on 30 users. Beyer and Holtzblatt also frequently encounter this issue and they challenge back with the question of what is the likelihood that we were able to find the one person who did a particular action. They encouraged the team to think of each user representing a million users. This also proved to be true during the latter part of our study as we began to see repeated behaviors among separate users in different locations. In addition, we were focused on user's intents rather than on a set of tasks. User's intents are more stable than their actions or preferences; actions and preferences may change once they upgrade to the latest software on a particular device, but their intents remain stable.

3.1.1 Affinity Diagram

The Affinity Diagram created by the team resulted in eight major affinity groups from which new designs could be created with promising results. These affinity groups include:

1. My Values Around My Car
2. Managing My Carried In Devices
3. Managing My Life's Digital Content
4. What I Do Besides Drive
5. Driving With Distractions
6. Finding My Way
7. Learning the Controls and Displays
8. Using the Controls and Displays

Each of the affinity groups contains a number of related sub-groups that were focused on by the design team during development of the next generation of in-vehicle systems and related services. Because the next generation system is not publicly accessible at the time of this publication, the examples that follow are of a more general nature to support the benefits of a Contextual Design approach. Specific details illustrating the wide-ranging return-on-investment (ROI) will have to be shared in future publications when the system is available to consumers and both media and user feedback has been received and reviewed.

One high-level example, where the design team "visioned" around and developed patents, was the finding that while driving through familiar areas, drivers do not require navigation assistance. We often observed drivers turning off the route guidance prompts when traveling in familiar locations and skipping recommended turns by the system because the driver knew a "better" route. Based on this information, the GM team developed requirements for a new navigation routing system that would learn where the vehicle has traveled and based on that information make more general routing instructions, as well as providing drivers information about how their route will be impacted if they choose to ignore a maneuver.

For example when starting from a Detroit suburb and traveling to Chicago, the system would prompt the user to get onto I-94 west while monitoring the driver's progress towards this goal without providing turn-by-turn prompts out of the driver's neighborhood. The frequency of prompts would increase when the vehicle recognized it was traveling in unfamiliar territory. This is very similar to the way in which people give instructions to drivers when they have knowledge about the driver's familiarity with the location in which they are currently driving.

Another high-level learning example was how drivers manage distractions in the vehicle. Participants were instructed to drive as they normally would, ignoring the obvious fact that there were two strangers riding along. Given this instruction, they were observed to use portable devices such as cell phones while driving and to actually manage, to a degree, the higher workload tasks associated with the phone.

We often observed participants doing a quick check of the phone's display when they had an incoming SMS or e-mail and then putting the phone back down while driving. Later, when stopped at a light or interim destination, they would read the SMS/e-mail and/or respond. When asked further about the observed behavior, the team realized what was going on. Many of the drivers had developed a triage approach to SMS and e-mail.

First, users needed to determine who the message was from; since their vehicle did not support the display of such information in a more convenient and safe manner, they had to pick up the phone. Next, based on the sender and the driving conditions, the user would make a determination whether to start to read the message or defer it to later, when stopped. If the decision was made to begin reading the message, the user would start and complete the task if it was a short message. If the message was long, the user would cancel out and place the phone back in its "at-hand" storage location to read the longer message when he or she were stopped.

Replies to messages were only observed to be done while stopped; however, we recognize this may have been due to the fact that we were in the vehicle with them. However, several drivers were observed to only check their phones for SMS/e-mail when they were stopped. One was quoted as saying "I don't want to die." The main point here was that drivers were aware of the distractions they were inflicting on themselves and many drivers exhibited some attempt to manage the distractions in a safer manner.

There are many more examples that team uncovered during this project and have applied in the design of the next generation of in-vehicle systems and supporting services at GM.

3.1.2 Sequence Model

The team identified six unique aspects to trips taken by drivers based on the contextual inquiry while creating the consolidated sequence model from all thirty interviews. The six phases identified were:

1. Organize self for trip
2. Start the car and get ready to leave
3. Begin to drive
4. Drive to destination + … (do everything else)
5. Reach an interim destination
6. End drive / reach final destination

Each phase affords unique opportunities for supporting a customer and allowing them to continue living their life while inside a GM vehicle. Vehicles need to support users' lives now more than ever. This discovery also drives the GM teams to think beyond just the car. Examples of this have already been put into production such as OnStar destination download, where GM customers can download destinations they have searched online to their vehicle to get route guidance instructions, all without having to re-enter the destination again when they get into their vehicle. Starting in model year 2011 vehicles, OnStar users are able to remotely access and control certain aspects of their vehicle, such as remote starting and unlocking the vehicle from their mobile phone. These design solution examples addresses the "Organize self for trip" phase of a trip. Additionally, GM customers are able to utilize "Pause and Play Radio" to pause a live broadcast and avoid missing important information while making a stop. This design solution addresses the "Reach an interim destination" phase of a trip.

3.1.3 Artifact Model

The consolidated artifact model revealed how participants used the available storage accessible to drivers and how, often times, storage designed for specific use by the OEM was used to store that item and everything else. The prime example is the cup holder. We observed participants placing loose change, electronic devices, charging cables, sunglasses, etc. into cup holders, even when the vehicle provides such device-specific storage elsewhere. When it came time to use the cup holder, we observed participants transferring junk in the cup holder to some other temporary storage location until the drink was finished.

Additional storage areas of note include the sun visor for CD's, garage door openers, and sunglass holders; windshields for portable navigation devices, toll transponders, and radar detectors. Cell phones could be found on the passenger seat, on the driver's seat between driver's legs or in their lap, on the driver's door in the door handle opening, and on the dash above the center stack (not to mention in the cup holder).

Finally, a big problem for those bringing in portable electronic devices was the management of power cables in the vehicle. We observed instances where people were charging two phones, running a portable navigation device and a portable entertainment device (e.g., portable satellite radio receiver or portable media player), and charging a laptop. This not only caused a cable management problem, but also a power supply problem as some cars only had a single cigarette lighter port (i.e., auxiliary power outlet) or, at most, two that were accessible from the front seat. Often times, the rear power outlet would be used by drivers with many brought-in devices, which made for interesting connection and disconnection observations.

During this initial project, the artifact model was extremely large, and somewhat difficult to use due to the team capturing all brought-in content storage and all vehicle controls, regardless of observed usage during the interview. To make the artifact model more manageable and useful to the design team, subsequent projects have limited the artifact model to capturing only those items that were observed to be utilized or discussed by the driver during the interview.

4. DISCUSSION

The adoption of a Contextual Design process at GM has proven to be successful and valuable in the design and development of user interactive systems in the vehicle. The experience gained from riding along with 30 people who were trying to entertain themselves and their passengers, communicate outside the vehicle, get information, and navigate resulted in what we believe to be a revolution in our designs of next generation infotainment and telematics products and services. The Contextual Design effort described here provided significantly more innovation to our infotainment and telematics systems design than GM's previous user-centered design methods of relying on the collective experience and wisdom of the designers/engineers and conducting usability tests to incrementally improve a design. This project alone resulted in over 180 new design ideas, from which 33 patent submissions were presented for approval, 8 were approved for patent filing, and 3 had defensive publications written.

The initial effort described here was so successful that we were given the funding to conduct four additional Contextual Design projects focused on such areas as younger drivers (age 16-25), drivers of full size pickup trucks for use in work, new vehicle ownership experience, and a replication of this study in the Europe and Chinese automotive markets.

The GM UX Design Team has taken the Contextual Design process [2][3] and Cooper's Goal-Directed Design process [4][5] and morphed them into GM's own UX Design process that is being adopted across the organization globally, which allows for a repeatable process, with known expectations and deliverables/results, and affords better communication across our global design teams.

Finally, this project underscores a challenge facing all designers of automotive user interfaces; that is, to provide the data and services that support users' goals in and around the vehicle, while minimizing or eliminating driver distractions. Even though there were several cities and regions that had handset-use restrictions in place, it is clear from observation in this project that drivers will continue distractive behaviors in order to be able to continue living their lives while traveling in their vehicles. Our objective, as an OEM, is to be able to support our users accomplishing their goals in our vehicles in the safest manner possible. This entails providing a suite of solutions that includes speech recognition for hands-free operation of in-vehicle systems and brought-in devices; warning systems such as speed, lane guidance, and car following that provide notification of degraded driving performance; automation of certain driving tasks such as longitudinal and lateral vehicle control; and finally, collision mitigation systems that reduce the effects of an accident on the occupants should one occur.

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