An Analysis of User Experience and Distraction In Automotive Infotainment Units

William Kenneth Boyd

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An Analysis of User experience and Distraction in automotive Infotainment units

by

William Kenneth Boyd

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An Analysis of User experience and Distraction in automotive “Infotainment” units

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ABSTRACT
The purpose of this study is to gauge the distraction of so-called “infotainment units.” Though many states regulate the use of handheld devices by drivers, few currently regulate the usage of in-dash infotainment systems, which provide many of the same services with little or no difference in User Interface. In this study and paper, we will use current practices in User Interface and User Experience analysis to compare emerging infotainment systems to the handheld devices they seek to replace.

Author Keywords
User Experience; Infotainment Units; Apple CarPlay; Android Auto; Driver Distraction

INTRODUCTION
As cell phones become more ubiquitous, more states are implementing “distracted driving” laws. However, the landscape of enforcement, or even implementation of such laws is varied. To date, 49 US states implement some form of “distracted driving” law (all except Montana). Missouri bans texting and driving for “novice/beginner” drivers only, while 22 of the remaining 48 states extend the ban to require total “hands free” behavior [1]. Though the definition of hands free is not always “well defined,” according to the National Conference of State Legislators, the state of Georgia’s hands free law is typical of a well-defined standard for law enforcement, and bans drivers from “physically holding or supporting a wireless communications or standalone electronic device with any part of the body” [2].

These laws have varying levels of enforcement. In some states they are backed by fines of varying degree, while other states impose license penalties or jail time. Most states allow a police officer to issue a citation for only this infraction (“primary enforcement”); however a few states only allow an officer to issue a citation for these infractions only if another infraction caused the officer to stop the driver (“secondary enforcement”) [3].

In the middle of this new frontier, car buyers have new demands. In addition to safety and performance features, buyers now seek non-empirical features designed to increase the car’s “desirability” [4]. With this change, gone are the manufacturer-specific radio units with varying levels of connectivity to various devices. In their place, smartphone ecosystem manufactures like Apple and Google have introduced new, sleek, and on-brand “infotainment units” that seamlessly bring the user’s phone into the dashboard. Better yet, these manufactures claim that their infotainment units are “optimized for the driving environment” [7] and put “driving safely” as the “driver’s first responsibility” [8].

These infotainment units, notably Apple’s CarPlay and Google’s Android Auto, connect to a user’s phone via a data interface. Once connected, the unit provides the user with a large yet streamlined subset of their phone’s full capabilities through their vehicle’s center screen, queuing music, following navigation, and making texts and phone calls from their phone through the infotainment unit and voice assistants. Thus, head units provide the familiarity of a user’s phone, while driving in the car, without the guilt of using a handheld device while driving.

User Experience (UX) is the idea that users of products, services, or objects experience a journey while using or thinking about a product/service. Qualitative or quantitative assessment of this journey (in aggregate) can demonstrate the users good or bad impressions or usage of a product. Measuring UX is a common place practice in industry where manufacturers seek to garner more sales by improving the UX of their product. In this study, we will attempt to gauge the distraction of such infotainment technologies while driving. Our experiment uses UX practices to compare the use of infotainment units to the handheld smartphones devices they seek to replace. We seek to ascertain how engaged users need to be in order to benefit from their use. This engagement will be weighed against how much they must disengage from driving to interact with the systems. Our two (2) fundamental research questions are:

1. How distracting is handheld usage while driving?
2. Is infotainment less distracting than the equivalent handheld distraction? If so, is this level safe?

LITERATURE REVIEW
Apple CarPlay and Android Auto are developed as part of Apple’s iOS and Google’s Android ecosystems, respectively. Though they are not compatible (an iPhone user cannot use Android Auto, and an Android user cannot use Apple CarPlay), many vehicle infotainment systems feature...
Apple CarPlay, Android Auto, and a manufacturer-specific system that can be selected through a menu button on the vehicle’s screen, or by plugging in a smartphone and letting the vehicle decide which to use. In terms of availability, both manufacturers claim “over 500 models” of car to choose from, and offer third party aftermarket units that replace factory-installed units in older models [12, 13]. When it comes to UI, both share some similarity; featuring limited abilities from the smartphone, encouraging a voice-driven user experience, and noticeably, lacking much of any interaction with the onboard CD, cassette, or radio antenna. When it comes to differences, CarPlay offers users a more iOS-like “home screen” to navigate through a list of their CarPlay apps, while Android Auto differs from its phone counterpart and attempts to provide a “single pane of glass” – a single screen for viewing an overview of music, texting, and navigation. To select an application, iOS users would navigate to the desired app on the home screen, then select it. Android users, on the other hand, would select the music, navigation, or texting element of Android Auto, then use a sub-menu to switch between the different apps that could provide that content (for example, getting music from Spotify vs Google Play) [5].

Research as to the role a phone should play in the car is mixed. Most scholarship indicates that intense and involved interaction with devices while driving leads to inattention to the road, however new research indicates that performing other, secondary tasks helps keep drivers sharp and alert, which in turn helps combat drowsiness [6]. Thus, manufacturers are increasingly moving towards in-car “infotainment” systems which acts as a quick gateway to performing basic tasks like texting, music selection, and navigation, but removing more complex tasks like searching for new music by song title, or reading reviews left for restaurants on a map. This trend is evident in both Apple and Google’s infotainment system user interface guidelines [7, 8]. Our study does not attempt to prove or disprove this notion; rather, it helps verify whether or not Apple and Google’s systems do, in fact, provide a fast and usable gateway for common phone tasks.

In addition to direct interaction with secondary systems, research also shows that involuntary distraction (i.e., distraction not caused by willfully engaging in a task) can also affect driver focus, which includes animations and other movement on an infotainment screen. Hoekstra-Atwood et al. have users in a simulator focus only on the road, not interacting with the screen on the dashboard at all. As they drive, images are shown on the unit. They report that involuntary distractions (as opposed to voluntary distraction, which they define as “any activity that could divert a person’s attention away from the primary task of driving”) can “capture attention automatically” [9]. In our study, we postulate that this may play a factor in Android user’s decreased performance with respect to involuntary popup notifications on Android Auto.

**METHODS**

**Participants**

The study had 20 participants. Users were recruited from undergraduate classes at the University of Alabama in Huntsville. Participants predominantly favored Apple’s iOS ecosystem (65%). Of the 20 participants, one (5%) reported driving a car with Apple CarPlay equipped, and one (5%) reported driving a car with Android Auto equipped. All (100%) reported using a smartphone “daily,” 65% reported driving a vehicle “daily,” 25% reported driving a vehicle “weekly,” and 2 participants (10%) reported “other,” listing 4-5 times a week, and 2-3 times a week, respectively. Four participants (20%) reported receiving a citation or warning for speeding in the last five years. Of the participants that reported texting while driving, 10% reported they texted while driving at least once a month, 20% reported texting and driving once a week, 20% reported texting while driving on a daily basis, and 5% of users reported texting and driving on an hourly basis. 45% of users reported not texting and driving. No participant reported having received a citation or warning for handheld device usage in the last 5 years.1

**Protocol**

Participants completed a series of forms during the testing. The forms included an Intake/Profile, Single Ease Question and Debrief (SEQ) and System Usability Scale (SUS) evaluations. The SUS scales were administered after each driving segment. Participants were asked to drive in the simulator while completing five (5) specific tasks; each task was estimated to take less than 5 minutes to complete. Users completed the tasks using the smartphone (tasks 2 & 3) and the infotainment unit (task 4 & 5). The order of tasks varied so that some users completed the tasks with the smartphone first and others completed the tasks with the infotainment unit first. A complete listing of tasks is found in Table 1.

**Procedure**

Participants were asked to indicate which platform they used most often: Android or Apple. Subsequent tasks used only the participant’s indicated device platform. After completing intake forms, participants were asked to situate themselves in a simulator and adjust it to their comfort. Once situated and familiar with the device, participants were told to begin driving through a simulated town to a freeway populated with other simulated drivers. Once they made it to the freeway, users were prompted to use one of the devices to perform a series of actions described above.

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1 One user (5%) evidently felt guilt over their honest answer, and notated their entry (“How often do you text while driving? Daily”) with a “frowning face.”
Once finished with these tasks, users pulled the vehicle to the side of the road and exited the simulator. They then filled out a System Usability Scale for both tasks while the simulator was reconfigured to use the alternate technology. If users used the handheld device first, the infotainment unit was configured to use the handheld device they used previously. If users used the infotainment unit first, the infotainment unit was turned off and the user was given the handheld phone. Once finished with the surveys, the user got back in the simulator and drove again. Tasks from the first section were repeated, and the user was asked to use the new technology instead of the previously used technology.

When using the handheld devices, users were asked not to use automated assistance for actions. When using infotainment devices, users were not allowed to use the handheld phone connected to the infotainment unit. In addition, on Android Auto, users were asked not to use the “canned responses” feature, which allowed users to respond to text messages with pre-planned responses using a single screen tap.

When the user finished the steps, they were again asked to pull the car over, exit the simulator, and fill out two more SUS evaluations. Finally, we asked them to fill out a short debrief form and give us any additional comments.

<table>
<thead>
<tr>
<th>Task#</th>
<th>Action</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction to the simulator</td>
<td>Drive to the expressway from town</td>
</tr>
<tr>
<td>2, 4</td>
<td>Send a Text Message</td>
<td>Respond to a message asking the user’s location with a response we prepared for them in advance.</td>
</tr>
<tr>
<td>3, 5</td>
<td>Select music</td>
<td>Open a specific playlist loaded onto the phone and select a song. Users were encouraged to skip through the playlist if they did not like the song or pause the music if they could not find anything they liked.</td>
</tr>
</tbody>
</table>

Table 1. Tasks the users were asked to perform. Tasks 2 and 4 and tasks 3 and 5 happened on the mobile phone and the infotainment unit, respectively

Study Environment
The study included the use of two smartphones (Android and iPhone) and a single infotainment device that we connected to either device. Participant interactions were recorded using a stationary video camera. Participants were also asked to wear eye tracking glasses that would record eye movements.

The study was performed in the RIDE Lab on campus, equipped with the L3 DeliverySim simulator [10]. Though this simulator is intended for 18-wheeler training, the software came prepared with smaller vehicles, and the side-mounted dash screen was removed. Attached to the dashboard was an infotainment unit. Tucked into the instrument cluster was a small wireless speaker.

Figure 1 shows the complete set of technology used. Figures 2 and 3 show the setup used with the simulator and vehicles.

When drivers used the handheld device, the infotainment unit was powered off. When drivers used the infotainment unit, the phone was plugged into the unit via a USB cable and set on the dashboard of the vehicle. The wireless speaker was connected to the phone or infotainment unit, depending on which technology was used. An assistant equipped with a second phone was used to send text messages, and playlists were loaded into the phone’s official music player (“Music” on iOS and “Google Play” on Android). The default texting application was used (named “Messages” on iOS and Android, but unrelated).

RESULTS
A plethora of data was collected during the study including time spent driving, errors committed during testing, number of times the drive looked at the device, as well as the SUS metrics in order to answer our research questions

1. How distracting is handheld usage while driving?
2. Is infotainment less distracting than the equivalent handheld distraction? If so, is this level safe?

How distracting is handheld usage while driving?
Studies linking handheld device usage to vehicular accidents and distraction have been performed, indicating a correlation between the two [11]. In addition, because texting while driving is illegal in nearly every state, and many states are expanding that ban to all handheld usage [3]. Therefore, measuring handheld device distraction provides a fairly uniform baseline to compare other car interactions with, from a user experience standpoint, as well as a legislative standpoint. While texting and driving, we noted that Android users looked at the device more often than iOS users for both categories (texting and using music). Table 2 shows the summarized results for how many times users looked at the device they were using (and, consequently, away from the road).

Drivers using iOS spent an average of 39 seconds texting, and 32 seconds selecting music. Android users spent slightly longer, taking an average of 45 seconds to text and 35 seconds to select music. This is shown in Table 3.

In addition to observations by the researchers, participant SUS scores indicated that texting while driving was an undesirable experience, as shown in Table 4.

Finally, when asked on a Likert scale from 1 (not very) to 5 (very) if the phone was distracting, users widely answered that it was distracting, as shown in Table 4.

Because of these measurements, we agree with previous findings on the ability of handheld devices to distract drivers. With this baseline, we can evaluate whether infotainment units, intended to reduce this distraction, actually do reduce distraction.
Several Android users ignored instructions to use voice commands and used the Android Auto-offered “canned messages” telling the recipient that they were driving and could not text.

These findings, as well as the observations of the drivers while performing their tasks, lead us to believe that infotainment units are at least as distracting as phones, to the user familiar with an ecosystem’s handheld offering, but not with the infotainment offering. Thus, in the current state of things, we do not find that this level of interaction is safe, using current legal and research standards. This is discussed in “Discussion.”

**Discussion**

As a result of our study, we believe Apple CarPlay to be generally less distracting to drivers than Android Auto. This is due to the smaller number of looks made by the average iOS user for any task (See Table 3), the subjectively better rating given by users in the debrief (See Table 4), and the observed interactions with the infotainment unit by researchers.

However, results were not entirely weighted in iOS’s favor. When texting, Android Auto was described as better (by Android users) than CarPlay was described (by iPhone users), based on SUS ratings (See Table 4). However, several

<table>
<thead>
<tr>
<th>Event</th>
<th>Handheld Texting</th>
<th>Handheld Music</th>
<th>Infotainment Texting</th>
<th>Infotainment Music</th>
</tr>
</thead>
<tbody>
<tr>
<td>iOS</td>
<td>Average</td>
<td>0:39:06</td>
<td>0:32:24</td>
<td>1:00</td>
</tr>
<tr>
<td>Count: 13</td>
<td>Std. Deviation</td>
<td>0:10:59</td>
<td>0:11:49</td>
<td>0:24</td>
</tr>
<tr>
<td>Android</td>
<td>Average</td>
<td>0:45:00</td>
<td>0:35:00</td>
<td>0:54</td>
</tr>
<tr>
<td>Count: 7</td>
<td>Std. Deviation</td>
<td>0:24:25</td>
<td>0:10:10</td>
<td>0:20</td>
</tr>
</tbody>
</table>

Table 3. Average and standard deviation of times spent performing individual tasks, grouped by ecosystem

Is infotainment less distracting than the equivalent handheld distraction? If so, is this level safe?

As with handheld devices, we noted that Android users looked at the device more often than iOS users for both categories (texting and using music) (See Table 2). CarPlay users performed music selection faster than Android Auto users but did not perform texting faster (See Table 3).

SUS scores were rather interesting for infotainment usage. With the exception of using music on CarPlay, users rated the infotainment unit as less usable than the handheld phone, with respect to the context of driving (See Table 4). However, users rated the infotainment system as less distracting than the phone when asked on the debrief form (See Table 5).

We believe that the Siri interface initially confused iOS users when texting, as they did not wait for Siri to prompt them after different steps in the Siri texting process. Android Auto seemed to wait less time between a user ending speech input and Android Auto prompting for the next input, which may have kept Android users from becoming “impatient” and trying to speak to Android Auto “out of turn.”

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>iOS</td>
<td>Average</td>
<td>1:11:30</td>
<td>28.44</td>
<td>1:22:00</td>
</tr>
<tr>
<td>Count: 13</td>
<td>Std. Deviation</td>
<td>0:22:49</td>
<td>5.29</td>
<td>0:34:34</td>
</tr>
<tr>
<td>Android</td>
<td>Average</td>
<td>1:20:00</td>
<td>31.4</td>
<td>1:22:24</td>
</tr>
<tr>
<td>Count: 7</td>
<td>Std. Deviation</td>
<td>0:34:36</td>
<td>6.91</td>
<td>0:32:26</td>
</tr>
</tbody>
</table>

Table 2. Average and Standard Deviation for the times a driver made eye contact with the handheld phone or the infotainment unit, as well as average and standard deviation for the time it took users to complete tasks on the handheld and infotainment units

<table>
<thead>
<tr>
<th>Event</th>
<th>Handheld Texting</th>
<th>Handheld Music</th>
<th>Infotainment Texting</th>
<th>Infotainment Music</th>
</tr>
</thead>
<tbody>
<tr>
<td>iOS</td>
<td>Average</td>
<td>4.8</td>
<td>4.08</td>
<td>3.31</td>
</tr>
<tr>
<td>Count: 13</td>
<td>Std. Deviation</td>
<td>2.82</td>
<td>0.95</td>
<td>1.03</td>
</tr>
<tr>
<td>Android</td>
<td>Average</td>
<td>4.71</td>
<td>4.14</td>
<td>3.71</td>
</tr>
<tr>
<td>Count: 7</td>
<td>Std. Deviation</td>
<td>2.64</td>
<td>0.69</td>
<td>1.11</td>
</tr>
</tbody>
</table>

Table 4. SUS score averages and standard deviations for participants, by ecosystem and activity

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>iOS</td>
<td>Average</td>
<td>59.42</td>
<td>65.77</td>
<td>60.19</td>
</tr>
<tr>
<td>Count: 13</td>
<td>Std. Deviation</td>
<td>21.19</td>
<td>19.77</td>
<td>24.95</td>
</tr>
<tr>
<td>Android</td>
<td>Average</td>
<td>63.21</td>
<td>72.86</td>
<td>68.93</td>
</tr>
<tr>
<td>Count: 7</td>
<td>Std. Deviation</td>
<td>23.79</td>
<td>17.58</td>
<td>26.8</td>
</tr>
</tbody>
</table>

Table 5. Average and standard deviation for overall infotainment enjoyment, phone distraction, infotainment distraction, and percentage difference, grouped by ecosystem
Android users avoided the dictation mechanism and sent a “canned response,” which was counted as a failure, as they did not follow instruction to type or dictate messages. CarPlay users, on the other hand, had a hard time using the texting feature for the first time. Rather than letting them select the message to listen to, CarPlay would read the unread messages to the user, then ask if they wanted to respond or cancel. This action seemed to confuse many first-time users, who expected to select the message, listen, and respond. In the end, most users were able to figure out their infotainment unit’s texting options, which could indicate that on subsequent trips, their proficiency with the system would have been markedly better.

Music selection was noticeably easier on the CarPlay system, and, in fact, it was the only SUS score that was better than its ecosystem and action’s handheld counterpart. CarPlay’s music app mirrors the iOS music app almost perfectly. In addition, while Android Auto uses little or no text to label buttons, almost all the buttons on CarPlay were clearly demarcated and labeled, making it seemingly easier for users to quickly assess which onscreen buttons to push. In addition to not using text labels, Android Auto did not use iconography that users understood. When asked to switch from one playlist to another, many users hit the button with the music note, but found that it took them to a selector for which app would play audio, not which playlist to pick. Only after trying other buttons did they land on the correct button to select a different playlist in the app.

Overall, we believe that while Apple CarPlay may be less distracting to iOS users than Android Auto is to Android users, we do not believe either are safe alternatives to handheld device usage. However, because our sample was almost entirely new infotainment users, we can make no claim as to its efficacy as a replacement for drivers already familiar with the infotainment unit.

CAVEATS AND FUTURE STUDY

Some of our results were undoubtedly affected by the dissimilar pool sizes between iOS users and Android users. In the future, more Android users should be recruited. Another impacting factor may have been many user’s inexperience. Though iOS users seemed to pick up the interface faster than Android users, Android users did eventually figure out the interface. This may indicate that over multiple usages of an Infotainment unit, satisfaction and usability would move closer to each other as users figure out how to use the interface more proficiently.

It should also be noted that since the performance of this experiment, both Apple and Google have released newer versions of CarPlay and Android Auto, as discussed in “Literature Review.” These changes bring the user paradigms of the two systems closer together and might warrant further study or A/B testing.

In the study performed, iOS and Android users were asked to type or dictate all responses, despite the fact that Android Auto features a “canned messages” function allowing users to respond with a generic message. A similar feature is in iOS and CarPlay, called “Do Not Disturb While Driving.” This feature silences all calls and texts sent to an iPhone while the user is driving their car (based on sensor data, or a connection to CarPlay). A predetermined response, changeable by the user, is texted to anyone who calls or texts the iPhone. There are various options for override (ex: a second call in 5 minutes will override DND and ring the phone; responding to an automated text with the word “urgent” will deliver the silenced text). In the future, iOS users might be asked if they use or would use such a feature.

Finally, a future study might include having Android users try CarPlay, and iOS users use Android Auto, to further differentiate system usability.

CONCLUSION

As legislative bodies and community outreach place more regulation and emphasis on distracted driving, more automotive manufacturers are equipping vehicles with systems advertised as less distracting. Because legislators and general society may not be informed on the potential benefits or detriments of these systems, research should be done into their efficacy before users and lawmakers tacitly endorse or decry such systems. Though there is great opportunity for change and bettering both user experience and automotive safety, user interface builders must take care to do so in properly tested and verifiable ways. This study shows that there may not have been such testing and verification before a “better system” was touted to users and manufacturers.

APPENDIX A: FORMS

In accordance with UAH Policy, all materials used in the study were reviewed and approved by the University of Alabama in Huntsville Institutional Review Board. Attached here are copies of all the forms given to a user.

Forms are available upon request to Will Boyd (will.boyd@uah.edu) or Dr. Joy Robinson (joy.robinson@uah.edu)
REFERENCES


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Student Name (printed)

Will Boyd
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5/5/2020
Date