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Technology and driver distraction— the need for industry guidelines

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There is an increasing trend towards more sophisticated in-vehicle information and entertainment systems. Many of these systems are designed to assist with the task of driving and navigation, but unless carefully designed, they can become a distraction. The distraction issue is complex: Older drivers and inexperienced drivers have different cognitive and sensory requirements than those of experienced drivers. Users who are unfamiliar with an interface suffer a greater level of distraction than experienced users. Worldwide national standards differ significantly. The Japanese standards are very prescriptive about the design, whereas the European and American standards are more principle based and share many similarities. Australia is one of the few developed countries that hold virtually no standards at all. Holden, together with Monash University Accident Research Centre have been researching this issue since 2001 and have developed an extensive knowledge base. When following good design principles, driver distraction is significantly reduced, e.g. a well-designed navigation system can be less distracting than using a traditional paper map or street directory. To codify the knowledge from this research, Holden is developing a set of design guidelines for minimising driver distraction. These guidelines could easily form the basis of a set of national standards. The Australian car industry needs to work together to produce standards applicable to this country. Low volume production runs mean that without local standards, Australia is destined to accept often inappropriate and mediocre "off the shelf" interfaces from overseas.

Introduction

In-vehicle information systems are becoming more sophisticated and common in cars today. Many luxury cars now come standard with navigation systems, integrated telephones, and various driver information systems all controlled from either a large central colour screen, or a combination of steering wheel switches and instrument cluster displays.

In a few years time, it is likely that most Australian cars will be fitted with these types of interfaces.

The implementation and useability of these systems varies widely. The examples that follow show some of the features and differences between the systems.

Today's driver interfaces

BMW's iDrive system has a centrally mounted colour screen controlled by a single large knob on the centre console (see Figure 1). This single knob is used for navigation through the menu system and can be rotated, pressed, or moved laterally in 8 directions. Driver centric information (eg. turn by turn navigation instructions) appears in a display in the instrument cluster to minimise eyes off road time. This system provides a driver interface to

the navigation system, integrated phone, radio, CD, vehicle diagnostics and status, trip computer, and many other functions.

Figure 1: BMW iDrive System

Figure 2: Mercedes COMMAND System – Centre Display and Controls
(Photo courtesy Mercedes Australia)

The Mercedes COMMAND (Cockpit Management and Data) system also has a centrally mounted colour screen (Figure 2)) and a driver centric display in the instrument cluster (Figure 3). Control is via 3 sets of hard buttons and menu navigation is via a turn and push knob. Like the BMW, driver centric information appears in the instrument cluster display to minimise eyes off road time. The Mercedes system also provides an interface and

connection to portable devices such as the Apple iPod (the dashboard multifunction display adopts the iPod title navigation).

Figure 3: Mercedes COMMAND System – Driver Display and Controls

The Audi system (Figure 4) uses a large centrally mounted screen with the controls on the centre console. Four buttons around the menu knob correspond to the four functions shown in the corners of the screen. The Audi system also has a screen in the instrument cluster and steering wheel mounted controls for driver centric functions.
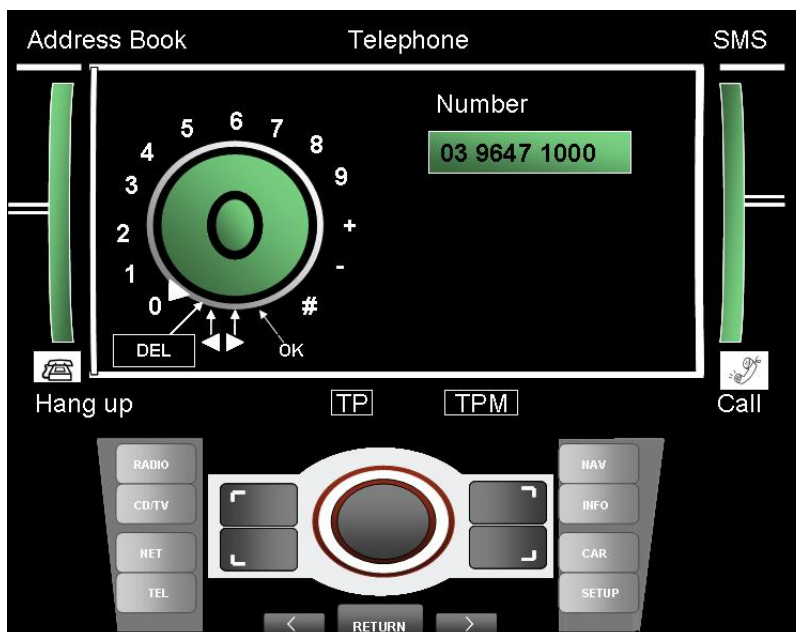
Figure 4: Audi Driver Interface

The Lexus interface (Figure 5) uses a touch screen supplemented by a number of hard buttons around the edge. This system has many functions including calendar and personal memo.
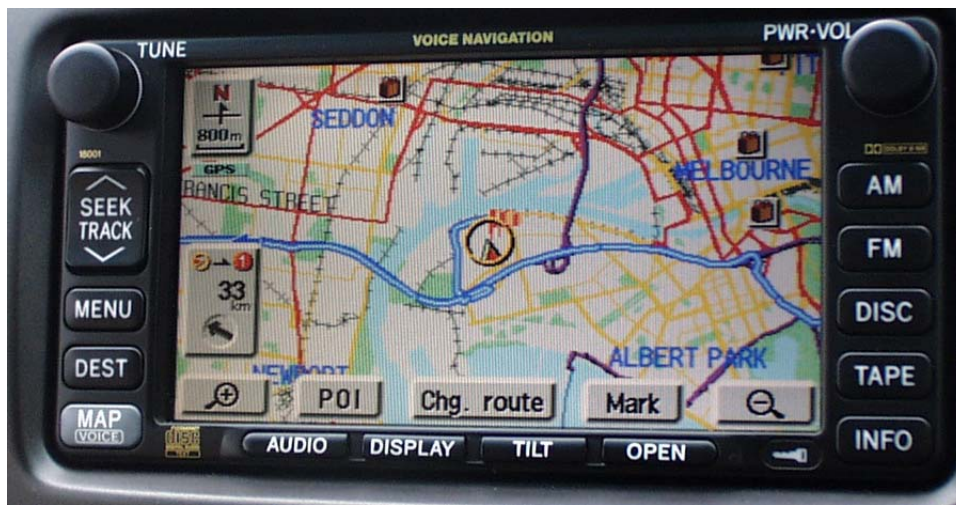
Figure 5: Lexus Touch Screen

The navigation system interfaces used by Ford and Holden in Australia comprise a centrally mounted colour display (Figure 6) and a remote control (Figure 7). The level of integration and customisation of these systems is lower than some of the other makes as the smaller annual productions runs (lower than 100,000 cars compared to 1 million plus for imported models) do not support the many millions of dollars investment required to fully integrate and customise these systems.

Figure 6: Holden Navigation Screen

Figure 7: Holden Navigation Control

Future trends

The next wave of change will come as vehicles become fully connected to the internet via Telematics. There is strong consumer demand for location based services such as traffic information, emergency callout, and motoring related location based information such as fuel and parking.

It is estimated that worldwide there will be 46 million vehicles equipped with Telematics by 2006 with subscriber revenues totalling US$8 billion (Harel, 2001).

GM North America recently announced that by 2007, Telematics will be standard fitment on all GM cars manufactured in USA. In Australia there are approximately 7,000 passenger cars equipped with OEM Telematics with a growth rate of 118% per year (Holden market Research 2004).

At the March 2005 Change by Design Conference, the Australian Telematics Industry Cluster demonstrated the "AT Signature" project, an example of location-based telematics services that will be available in the very near future (Figures 8-12 for examples of the various screen displays for services). These services included traffic information, traffic camera pictures, nearest fuel stations and prices, nearest car parks and prices, home automation control, weather, and other information.
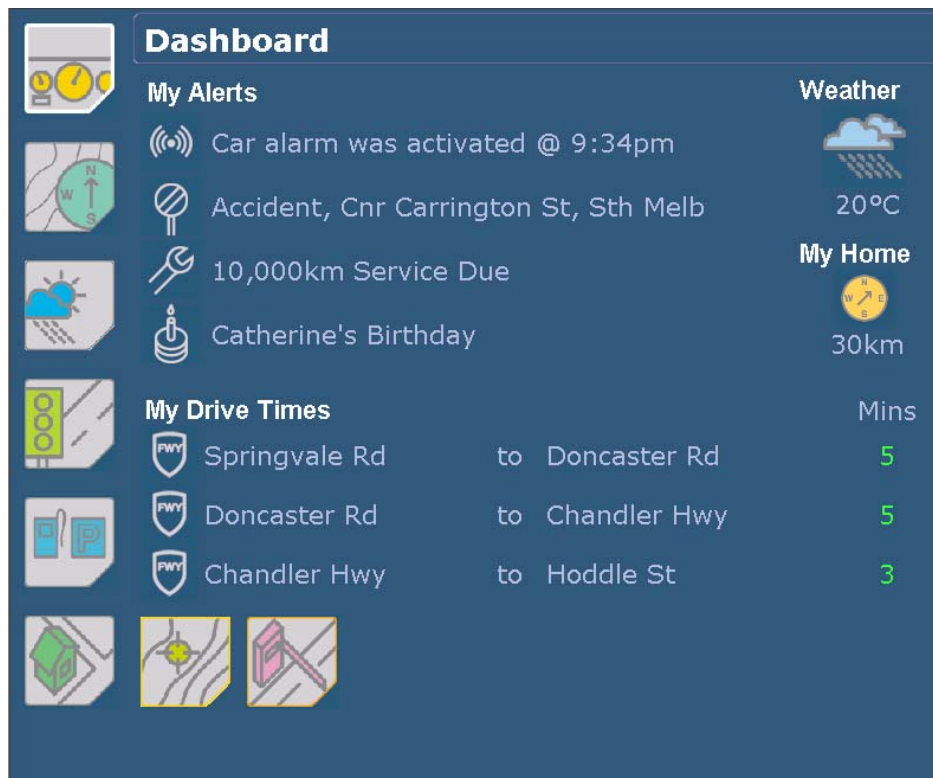
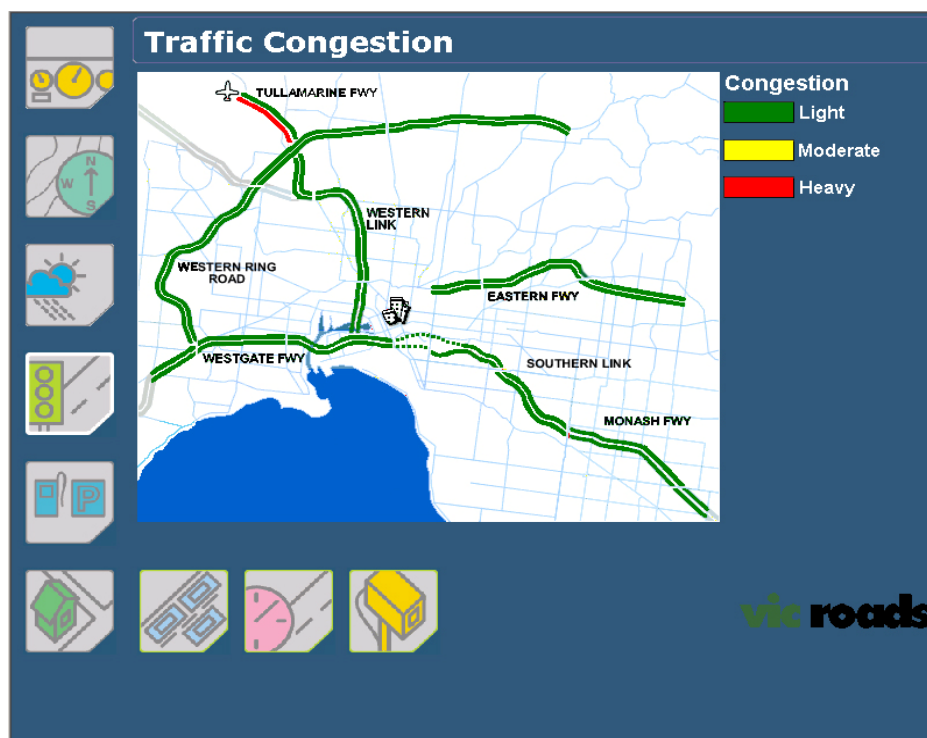Figure 8: AT Signature Startup Screen

Figure 9: AT Signature Traffic Congestion Screen

Figure 10: AT Signature Traffic Camera Screen
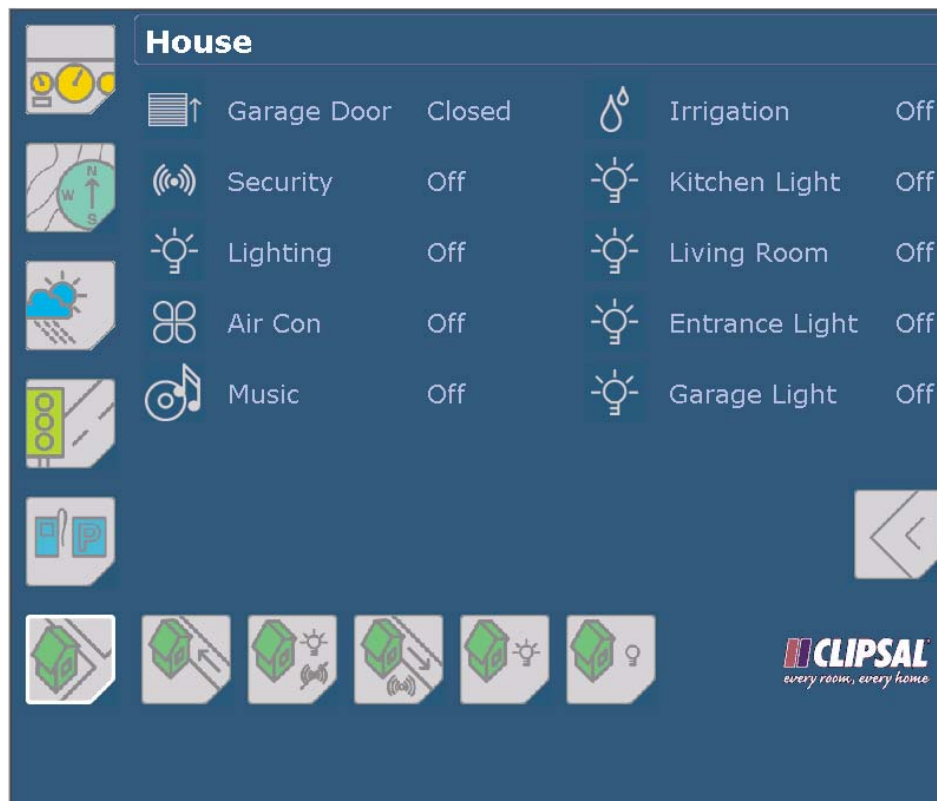

Figure 11: AT Signature Fuel & Parking Screen

Figure 12: AT Signature Home Automation Control Screen

System design and driver distraction

Many of these systems are designed to assist the driver with the task of driving and navigation, but unless carefully designed, they can become a source of distraction to the driver.

To minimise distraction, a system must have sound basic ergonomics, i.e it must be easy to learn and intuitive to use. In addition, the system must have specific design features to reduce distraction; such as task chunkability and the user control over the pace of interaction with the system. The system must have design features to individually address the 4 types of distraction: Visual, Auditory, Biomechanical, and Cognitive (Regan, Young, & Hammer, 2003).

If an in-vehicle information system is designed with these attributes, it will provide safer means for the driver to access information than other alternatives. For example there are many studies that show that a well designed turn by turn navigation system is less distracting than using a paper map (Dingus, McGehee, Hulse, Jahns, & Manakkal, 1995, Srinivasan & Jovanis, 1997, Regan & Young, 2003, Regan, Young, & Hammer, 2003, Perez, 1995).

The people

A fundamental element to any driver distraction consideration is the human involved. Despite technological advancements and developments which increase a vehicle's autonomy to sense, control and navigate the road, there will always be a human involved to

affect the driving task. As a result, the people involved in the driver distraction issue add another level of complexity to its study.

Older and inexperienced drivers have different cognitive and sensory requirements than those of experienced drivers. It is also likely that users who are unfamiliar with an interface suffer a greater level of distraction than experienced users.

The successful development of effective design guidelines must consider these influencers and accommodate for them. These influential areas are discussed in more detail below.

Differences due to age

A number of separate studies have revealed that age can affect the relative distracting effects of in vehicle devices. Results from data collected by Lam (2002) suggests that of all age groups examined, drivers in the 25-29 year age group had the greatest risk of being involved in a fatal or injury crash when using a hand-held mobile phone. It is believed by Lam that this result is due to differential exposure to mobile phone use across age groups – the 25 to 29 year age cohort may be more likely to use their mobile phone when driving then their older counterparts and this increased exposure increased their likelihood of crashing.

Lam's results must be juxtaposed against those found by McKnight and McKnight (1993). McKnight and McKnight studied the effects of conversation as well as dialling. In a driving simulator, subjects were expected to respond appropriately to various highway situations under several conditions of distraction. Their results suggested that the risk of being involved in a fatal or injury crash from in-vehicle distractions (i.e., attending to passengers, tuning the radio, smoking, adjusting the CD player) increases with increasing driver age. This effect has been attributed to the decreased ability of older drivers to share attention between two concurrent tasks.

Reed and Green (1999) observed that older drivers (aged 60+) showed greater decrements in their ability to maintain speed and lane position than the younger participants aged 20 to 30 years during driving simulator tests whilst making calls on a hand held mobile phone.

In a test track study conducted by NHTSA (2000) it was found that older drivers (aged 55+) were no more distracted than younger drivers (below 35 years) by voice input but were more distracted than the younger drivers when using the visual/manual interface during a destination entry and phone dialing trial.

Regan et al (2003) have found that older people (aged 60+) display greater decrements in their ability to maintain speed and lane position than younger participants aged 20 to 30 years, when using a mobile phone. The closed road testing was carried out in November 2001, the bulk of the research completed in 2002, and the report was completed in 2003.

Tijerina et al (1998) found another age difference when examining the distracting effects of entering destination information into different route guidance systems while driving. When using a visual-manual destination entry system, drivers aged less than 35 years took, on average, over one minute to enter destination information into the systems manually, while drivers aged over 55 took twice as long to perform the same tasks.

Despite these findings older drivers are not over represented in fatal and serious injury crashes (Hull, 2001). Observations during Holden testing (2003) indicated that older drivers are less willing to engage in distracting tasks whilst driving than younger drivers.

Figure 13 shows that young novice drivers represent only a minor proportion of the licensed population (14% in Victoria in 2002) yet are substantially more likely to be involved in road crashes, fatalities and injuries than older, more experienced drivers (about four times more likely in Victoria) (Hull, 2001).
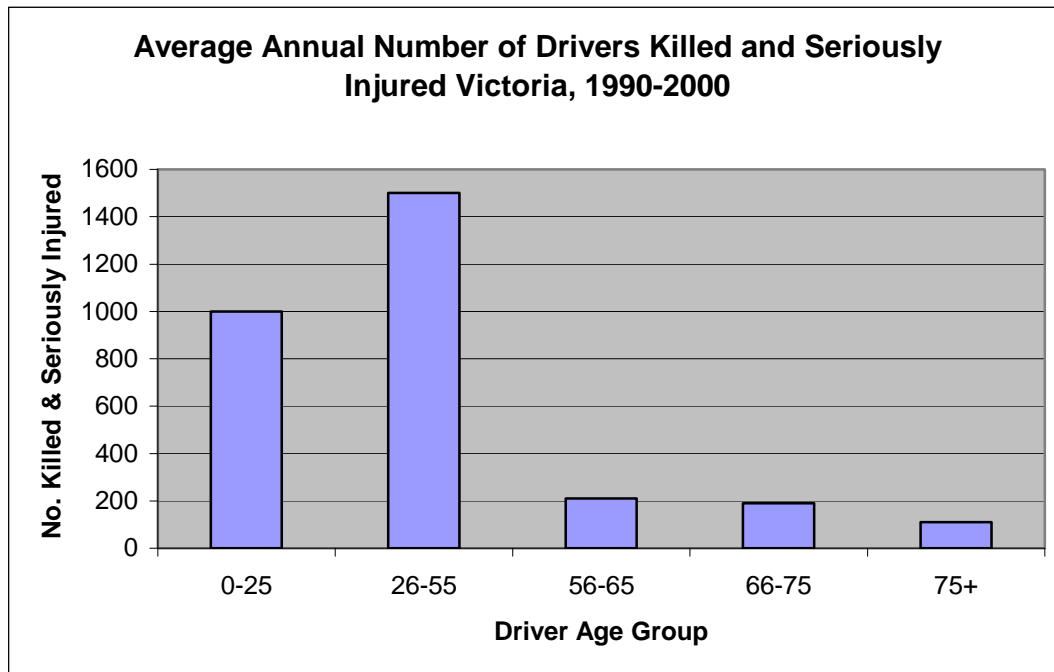
Average Annual Number of Drivers Killed and Seriously Injured Victoria, 1990-2000

Figure 13: Drivers Killed and Seriously Injured in Victoria (Hull, 2001).

The people most likely to use these technologies (the younger generation) are also in the category most likely to result in death due to collision.

In a study by Massie, Campbell and Williams (1995), women have been found to have slower reaction times, greater susceptibility to distraction and perceptual errors and poorer spatial abilities than men.

A task that is simple for one person can be extremely difficult for another person. During Holden's interface ergonomics study (2003) users from various age groups were given five simple tasks to perform. Some users completed the tasks in a short time and others were unable to complete the tasks after 45 minutes.

To design a system that minimises driver distraction, it first must be fully understood. The usability of a system is highly subjective. An interface targeted to a tech savvy user might be unusable to a novice, or a system designed for the inexperienced may frustrate an experienced user. To fully understand the differences between users and the effectiveness of a range of systems, testing has been carried out internationally.

Differences due to driving experience

An on-road study conducted by Wikman and colleagues (1998) examined experienced and inexperienced drivers eyes off road time and lane deviations as they tuned a radio, changed

a cassette, and dialled a mobile phone. The novice drivers made more short (less than 0.5 second) and long (more than 3 second) glances away from the road, which were associated with large deviations in lane position.

Young et al (2003) have found that tuning a radio while driving appears to have a detrimental effect on driving performance, particularly for inexperienced drivers.

Differences due to familiarity with interface (training)

It is likely that familiarity with an interface reduces distraction, but little research has been done in this area.

The research

Holden, together with MUARC have been researching driver and safety related issues since 2001, and has developed an extensive knowledge base. The research includes the following areas:

- Driver distraction including a driver's willingness to engage in potentially distracting tasks relative to driving conditions (young/old, experienced/inexperienced).
- How people interact with interfaces, do they use the intended method?
- Older drivers
- Hazard recognition (vision / night vision)
- Lane departure warning
- Drowsiness detection
- Child safety
- Human body modelling

This paper covers research results relevant to the design of in-vehicle information and communication systems.

A well designed in-vehicle system must satisfy 2 criteria: first, it must have good usability; and second, it must follow specific principles to reduce driver distraction.

A system that has good usability will focus on sound ergonomics and design principles. The system must cater for both inexperienced and experienced drivers. Ergonomic and design factors have played a major part in the design of vehicle interiors for many years. Designing a vehicle around driver distraction is a relatively new concept. Guidelines, or suggestions for how to reduce the distraction of an in-vehicle system, are sparse and differ significantly. In order to better understand this issue, research and testing has been conducted worldwide.

Research by the National Highway Traffic Safety Administration (NHTSA) estimates that driver inattention in its various forms contributes to approximately 25 percent of police-related crashes. Driver distraction is one form of driver inattention and is claimed to be a contributing factor in over half of inattention crashes (Regan et al., 2003). A study by Glaze and Ellis (2003) attributed the following percentages to crashes involving distraction from in-vehicle systems:

Distraction Source	% of Reported Distractions
Adjusting radio, cassette, CD	6.5
Adjusting vehicle climate controls	3.6
Using / dialling mobile phone	3.9

The instances of reports pertaining to technology distractions (FARS – Fatality Analysis Reporting System) have been steadily increasing since 1991 (Tessmer, 2000) and with the increase in the uptake of features like in-vehicle communication, entertainment and assistance devices, will continue to rise.

The following table describes the increase in driver's attention that highly complex tasks have.

Task	Average Glance Time (seconds)	Average Number of Glances
Check fuel gage	1.3	1.2
Complex radio task	1.1	4.0
Navigation with traffic info	1.5	5.8
New in-vehicle task of low complexity	1.4	10
New in-vehicle task of moderate complexity	1.6	18
New in-vehicle task of high complexity	1.8	35

Figure 14: Eyes off road time for various technology tasks (Dingus, 2000)

Technology-based driver distraction

Mobile Phones (Regan et al, 2003)
- Research has found that using a hands-free phone while driving is no safer than a hand-held phone.   Using a mobile phone while driving can increase the risk of being involved in a collision by up to four times.
- Mobiles phones cause both a physical and cognitive distraction and when used while driving, can significantly impair a driver's visual search patterns, reaction times, decision-making processes and their ability to maintain speed, throttle control and lateral position on the road.
- Sending a text message is more distracting than simply talking on a mobile phone.
- Talking on a mobile phone is more distracting than eating a cheeseburger.

Route Guidance systems (Regan et al, 2003)
- Entering destination information is believed to be the most distracting task associated with the use of route guidance systems; however use of voice input technology has the potential to reduce the distraction associated with this task.
- The least distracting output of information is simple turn by turn instructions.

- A well designed turn by turn navigation system is less distracting than using a paper map.

Entertainment systems (Regan et al, 2003)
- Research suggests that even the simplest of entertainment features such as listening to a radio, can impair driving performance.
- Operating a CD player while driving is more distracting than dialling a mobile phone or eating a cheeseburger.
- Changing a CD is one of the most distracting tasks a driver can perform.

Countermeasures

One suggestion to reduce the risk of crashing when preoccupied is the use of crash avoidance technologies. These systems warn the driver when they are entering into a potentially dangerous situation and allow them to correct before incident. Crash avoidance technologies include:
- Speed sign recognition
- Expanded feature-based recognition
- Lane departure warning
- Front collision warning
- Blind spot collision warning
- Night vision
- Pedestrian detection
- Distraction warning

The introduction of these vision and radar based technologies is expected to reduce some of the risk of crash due to driver distraction.

What does the customer want?

Research shows the customer knows exactly what they want from their vehicle. Feedback from Holden customers clearly shows that they do not want to be patronised by over simplistic systems. The customer desires the following:
- The ability to use in-vehicle information systems even if the vehicle is in motion.
- The ability to customise features and interfaces e.g. Antenna height preset or type of information displayed on the dash (e.g oil pressure, tachometer, radio presets)
- Satellite navigation, traffic reports to avoid delays, reversing cameras
- Cruise control that assists in speed reduction – i.e. can be set to NOT exceed a set speed
- The ability to use iPod/MP3 and personal organiser devices in the vehicle, fully integrated with steering wheel controls
- High level of automation, e.g. wipers and headlights that work on their own - no need for switches or controls expect in case of problems.
- Infotainment for families (i.e. rear seat entertainment)
- Garage and gate remotes built into the car
- Heads up speed display in different display sizes to cater for the elderly
- Indicators as thumb buttons on the steering wheel

When designing an in-vehicle system and interface, the customer's requirements should not be forgotten. A distraction-free vehicle is not successful if the customer will not purchase it. The vehicle must reduce distraction but still address the customer's needs.

Holden & Monash University Accident Research Centre driver distraction testing

To better understand what contributes to driver distraction and how it can be prevented, Holden and the Monash University Accident Research Centre (MUARC) have run three phases of testing on various infotainment systems.

The first phase measured the relative driver distraction of different systems and their ease of use. The second looked at which features were most commonly used and the third compared different methods of entering information and carrying out tasks.

The aim of this testing was to determine what contributes to well designed and badly designed in-car features. A range of participants in different age brackets and of different technical experience were selected in order to give an accurate user perspective. Test results indicated that a desirable interface should provide the following characteristics:
- Minimises driver distraction
- Supports both novice and experienced users, and
- Optimises driver satisfaction

Phase 1
Phase one of the testing had each participant drive three of five luxury cars from different manufacturers for an hour. Participants were selected from various age groups and both novice and expert users of the interfaces were included. They were given familiarisation time and then asked to perform a set of tasks while both stationary and driving.

The tasks:

Complete when stationary

Task 1
- Set climate control temperature to 20 degrees throughout the car.
- Set vent to re-circulated air, then back to fresh.

Task 2
- Manually tune radio station 105.1 FM and store it in preset number 1.
- Manually tune radio station 774 AM and store it in preset number 2.

Task 3
- Enter your home address into the navigation system and start guidance.

Task 4
- Insert CD into unit and select track 5.

Task 5
- Phone Person X on —— —— and leave a message on his answering machine saying what you are doing today (if relevant).

Complete when driving

Task 1
- Set the passenger climate control temperature to 17 degrees.
- Put warm air on the windscreen.

Task 2
- Seek radio station 105.1 FM and store it in preset number 3.
- Seek radio station 774 AM and store it in preset number 4.

Task 3
- Enter 241 Salmon St, Port Melbourne into the navigation system and start guidance.
- Drive a short distance and stop guidance.

Task 4
- Select CD mode and start CD playing Track 9.

Task 5
- Phone Person X on ——— ——— and leave a message on his answering machine saying that you are nearly done.

Some of the participants had little problem completing each of the tasks when stationary, but others could not complete the tasks within the 45 minutes, even with the vehicle stationary. Similar results were obtained in the dynamic testing, but it was also observed that many of the older participants would not attempt the more complex tasks while the vehicle was in motion.

Although the expert and novice users each responded differently to the tasks, there were consistent points which emerged, these included:
- When instructions were given, a minimalist approach was preferred.
- Logical menu structure
- Fade out / in of audio before / after voice instructions
- Predictive text on data entry and greying out of non selectable text
- Touch and drag of map
- Combination of touch screen and hard buttons preferred
- Pop-up information box gives you more information, when you touch an icon on the screen
- Higher screens were preferred
- A back button on all screens, but it must be in the same position on each screen.
- Help Mode - Different Levels
  - First Time – Interactive Lessons
  - Beginner – Section of screen dedicated to help
  - Intermediate – Popup help screens
  - Advanced – No Help, short cuts
- Input feedback is critical
  - Auditory feedback (e.g. beep when touch screen)
  - Visual feedback (e.g. GUI with menu options)
  - Tactile feedback (e.g. convex / concave, rocker, textured)
- An important consideration regarding the distraction of the system is the position of the screen. User's clearly felt uncomfortable looking away from the road, and preferred a screen position which is located within easy reaching distance and

viewing position from the driver, whilst maintaining the road traffic in their peripheral vision.

Phase 2

The second phase of testing asked six experienced drivers to record, over a 4 day period all tasks/features used from the following systems and the number of times used:

- Radio/CD
- HVAC (Heating, Ventilating, and Air Conditioning)
- Trip Computer
- Speed alert
- Cruise control
- Mobile phone usage
- Satellite navigation

The following tables identify the most frequently used functions and the total number of times each function was used (Figures 15-16).

Feature	No. Times
Audio - Radio	142
Audio - CD	46
HVAC	65
Cruise Control	29
Navigation	21

Figure 15: Feature frequency

Task	Feature	Mode of operation	No. times
Adjust Volume			**59**
	Radio	Steering wheel switches	34
	CD	Steering wheel switches	14
	Radio	Centre console	5
	CD	Centre console	6
Adjust Presets	Radio		**52**
	Radio	Steering wheel switches	45
	Radio	Centre console	7
Adjust Temperature	HVAC	Centre console	**30**
Set Cruise control	Cruise control	Steering wheel stalk	**29**
Change mode FM/AM/CD	Audio		**27**
	Audio	Steering wheel switches	23
	Audio	Centre console	4
Mute			**15**
	Radio	Steering wheel switches	10
	CD	Steering wheel switches	3
	Radio	Centre console	2
Turn off	Radio	Centre console	**12**
Cycle through trip computer	Trip computer	Trip controls	**10**

Figure 16: Task and mode of operation frequency

To design a system that minimises driver distraction, these frequently used functions need to be as simple as possible, preferably available via a single button press.

The results indicate that the most commonly used features in a vehicle are the audio functions, with the most frequently used being volume adjustment followed by radio preset selection.

In most cases, where possible, the steering wheel switches were used in preference to the centre console controls. The centre console control appeared to have been used when the task was following previous centre console interaction, e.g., HVAC or loading CD.

Phase 3

The aim of the third phase was to test the usability of three types of prototype human machine interfaces: the push button interface, the steering wheel switches and the touch screen. Representative tasks were chosen that would enable comparisons between the interfaces to be made. These were:

- Tuning the radio
- Adjusting the radio volume
- Programming a new destination into the navigation system
- Changing the map scale in the navigation system
- Selecting a phone number from the mobile phone address book and dialling it

Participants rated on a four-point scale the difficulty of completing each task. The scale ranged from (1) very easy to (4) very difficult. Observers also rated how easily the participants completed the tasks. There was a high level of agreement between the users and observers ratings, so the users ratings were used for this analysis. Ratings for each task for each interface were averaged to provide an easy way to compare the difficulty of using each interface. The average ratings are shown in the table below (Figure 17).

Task	Touch screen	Push button	Steering wheel
Radio station	1.09	1.00	1.09
Volume	1.18	1.00	1.00
New destination	1.81	2.36	2.18
Map scale	1.00	1.09	N/A
Phone number	1.44	1.72	1.40

NB. 1=very easy, 4=very difficult

Figure 17: Difficulty ratings of a range of interfaces

At this stage, only static testing (vehicle stationary) has been completed. Generally, tasks are much easier to perform statically than dynamically. It can be assumed that the degree of difficulty would be different in a dynamic situation, and the preferred type of interface may therefore change.

Familiarity

The Holden/ Monash University Accident Research Centre Phase 1 tests clearly showed that familiarity aided in the identification of the functions of various components/features. For example, almost all of the participants had never before used a navigation system, whilst all had used an air-conditioning system. Therefore it was evident that all of the

navigation systems were distracting to a high degree, while the air-conditioning system was less so.

This was also evident in phase three testing: As expected the difficulty ratings for the radio station and volume control were low, i.e. they were familiar tasks. Programming a new destination and retrieving a mobile phone number however, were more difficult.

There was a great variation in the method of operation between the different vehicles in phase one testing. Although each user may have been familiar with the task requested, they still had difficulty due to a lack of familiarity with the system.

When considering the driver distraction issues, differences between a vehicle's operating system become a major issue. A task performed regularly in one vehicle might pose a very low distraction, but when the user drives an unfamiliar vehicle, the task increases in difficulty and is a lot more distracting. This can also be said for model upgrades and new models within one manufacturer's range. A set of industry standards or guidelines would significantly assist in a driver's ability to change vehicle and operating systems comfortably.

Nissan and Renault have taken the first step in addressing this issue: both have developed a common navigation and communication system. Regardless of the background behind the joint venture, this move will benefit the industry. The system will share a common core which includes the system architecture, the hardware of the main control unit, the multimedia network, and menus and functions of the navigation and the mechanism of the audio-visual control unit. However, the look and feel of the user interface will be different between the two brands to allow them to keep their own identities (see www.nissan-global.com/EN/index.html).

Interface / input method

The preferred interface or interaction method will depend on the user, their experience and the task being performed.

The addition of more advanced and sophisticated systems into vehicles for greater driver comfort and convenience has the effect of increasing the potential for driver distraction. Internationally there has been big push to develop low distraction interfaces. Various methods of input and output are being trialled and tested to determine the best mix for increased safety. The input/output methods include:
- Hard switches – Centre console switches
- Touch panels/screens
- Steering wheel switches and stalks
- Voice recognition/activation

Centre console

The traditional layout of a screen and hard menu buttons and controls has the advantage of being able to be used without the driver looking, as their location and feel can be memorised. The separation of the buttons from the screen however, sometimes means that there is little logical relationship between the two. For example many Heating Ventilation and Air Conditioning (HVAC) buttons output information to a screen, located in a different region of the console. Some test subjects had difficulty making this connection.

Touch screen

Touch screens are generally seen as easy to understand and intuitive, but give no tactical feedback and require more eyes off road time than hard buttons. When glancing between the road and screen, the driver must adjust his/her focal length (Sansanouchi, Ishiai, Tanka, Yukawa, Hu, 2005), increasing the risk.

Phase 3 testing found the touch screen to be the preferred method of input for both the navigation and phone functions. Participants who rated the touch screen as the most preferred interface cited the ease of use and high visibility of functions as the reasons for their preference. They found it easy to see what to do, quick to locate functions and found inputting data quick, simple and easy. These factors become critical when the driver is performing a task whilst driving. The lesser the time spent on the task, generally the less distracting it is.

Voice control

Voice control is the obvious solution to reduce the risk of using complicated in-vehicle technology, as voice is not a modality that has to be time shared with the driving task. Studies have been conducted internationally, comparing the risk of using the voice and conventional systems (Tijerina, Parmer, Goodman, 2000).

Results of one particular test indicated that, on average, the system with visual-manual methods of destination entry was associated with lengthier completion times, longer eyes-off-road-ahead times, longer and more frequent glances to the device than the voice system.

Another study found auditory information or displays have a 30% increase in reaction times and a significant increase in cognitive workload (Lee, Caven, Haake, Brown, 2000).

Steering wheel switches

Phase 2 testing showed, that for tasks where both steering wheel and console switches were available, the steering wheel switches were used in 85% of cases. Phase 3 testing also found the switches to be convenient because less movement was required. It was rated as easy to use while driving, because it required only minimal time with eyes off road and hands off the steering wheel. Lack of feedback from steering wheel switches was also reported.

Steering wheel switches are often seen as a solution to reduce driver distraction. By putting frequently used buttons on the wheel, the driver can access them without moving their hands or significantly averting their glance.

The Citroen C4 (see Figure 18) has taken steering wheel control to the next level. There wheel features 4 rotary dials and 16 buttons.

To a user unfamiliar with this vehicle, the steering wheel and its controls may require a period of familiarisation before they can be used easily. Therefore this introduces the issue of vehicle training.
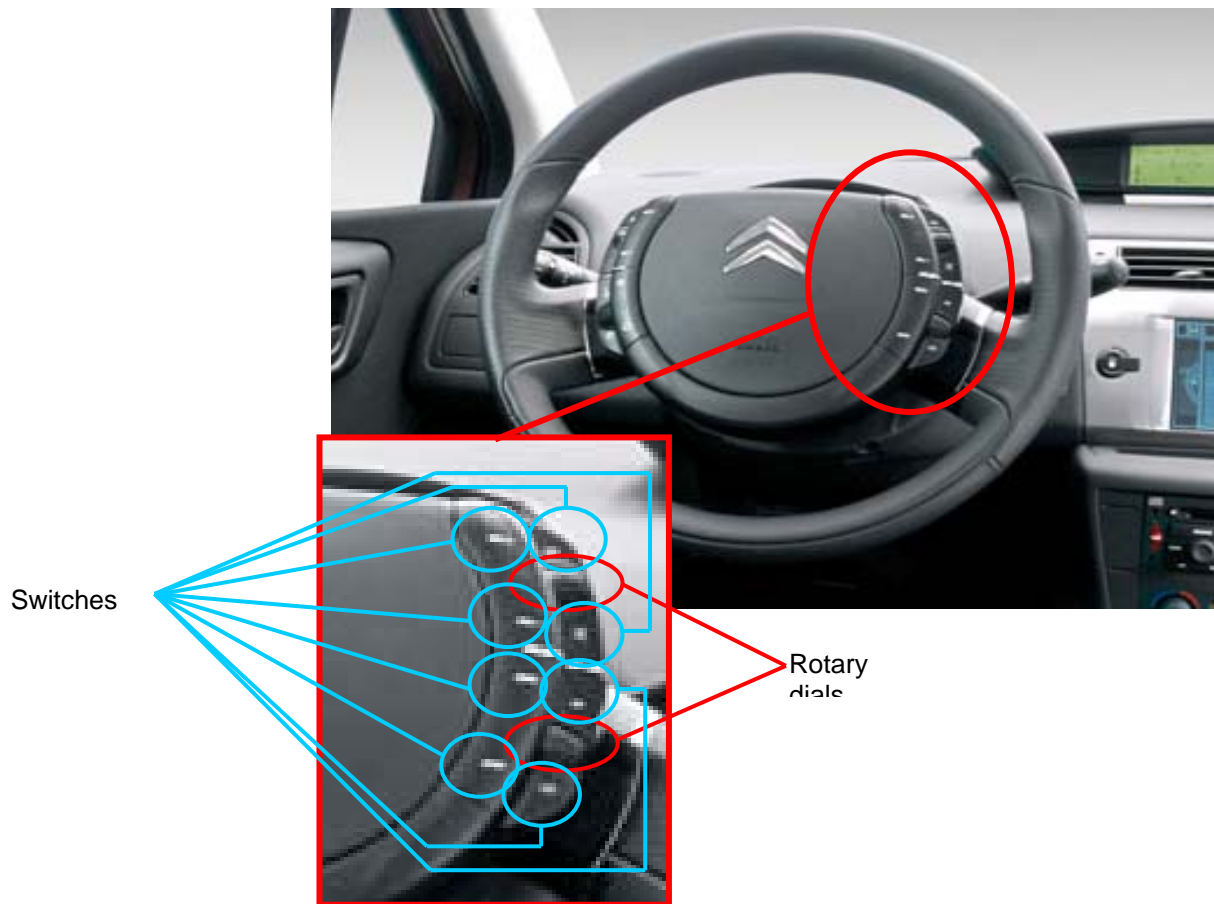
Figure 18: Citroen C4 (Photo courtesy Citroen Australia)

Training

BMW sales staff give prospective buyers a 20-minute demonstration of the iDrive interface before a test drive and then for those who buy the car, a one-hour training session before they leave the dealership. The car owners are invited back a week later for more detailed instructions.

Task Time

BMW's iDrive combines most infotainment functions into one knob. Changing the bass or treble settings on the audio system is a six-step procedure. In a conventional car with dials, this takes seconds (Lee et al, 2000)

Guidelines

Holden is developing a set of guidelines based on industry and academic knowledge learned from this research, aimed at minimising driver distraction by being intuitively easy to comprehend and understand and possessing specific features to facilitate time sharing of tasks. Holden recommends these guidelines form the basis of a set of national standards specific to the Australian context.   They would be easy to implement and avoid the

confusions and discrepancies encountered from simply translating a set of overseas standards (e.g.. NHTSA, JAMA or EU) to Australia.

From a technological perspective, everyday information technology use has become (is) the norm in Australia. Consequently, car manufacturers channel their efforts into providing functions that offer both information and the traditional focus of entertainment. However, before a customer will pay for either an information or entertainment function, its benefits must be clear and it must be useable. Therefore, consideration must go into how much technology a driver can handle both while they are driving (safety) and in terms of their ability and desire to interact with technology. That is, can, how and what applications may be added that do not distract from the primary task of driving or confuse the driver with technology they do not desire?

When defining standards and guidelines customer and user feedback is critical. In order for a well designed system to be successful in the market place it must appeal to the consumer. Frequently used functions must remain in prominent positions, and functions locked out while driving must not frustrate the user. The user's needs can be captured by adhering to the following 5 high level points:

- The interface must match driver situations;
- The interface must be seen as useful to the driver;
- The interface must be easy to learn;
- The interface must be easy to use; and,
- The interface must minimise driver distraction.

Holden is in the process of developing a set of Human Machine Interface (HMI) Design Guidelines with a set of three distinct deliverables:

1. Heuristics – A collection of rules of thumb that are easily accessible and digestible for its audience and forms the core of any HMI guideline work

2. Style Guide – A document to be used by those with creative licence looking to generate a HMI. The intended audience for this guide are automotive design departments

3. Checklist – A document aimed at engineers and software developers comprising a set of rudimentary points to be checked off when building or after completion of an HMI to ensure adherence to core driver distraction minimisation and ease of use principles

The application of these Human Machine Interface Guidelines should follow the sequence below (it is recommended that this method be followed every time the guidelines are utilised):

- Analysis - user analysis to understand the user and the user's context.
- Requirements specification - task analysis based on the user, the tasks they will want to perform, how often, their information requirements and the available technologies.
- Design - details of the design such as menu structure, screen design, icons and graphics.

Following this sequence will capture the benefits that should be captured in an HMI if the driver distraction is to be considered seriously. The next section will outline the heuristics Holden has identified with an elaboration and example for each.

Heuristics

Below are the heuristics (or 'rules of thumb') that are to be adhered to when constructing a well designed, intuitive and user friendly interface.

- Be consistent (in layout, structure, rules etc.)
- Provide a clearly marked exit(s)
- Provide assistance
- Present information in an expected display format (know the user)
- Minimise the memory load on the user
- The user must always know what is happening, feel in control and control the pace of the interaction
- Information should be grouped according to task, function and sequence principles
- Allow for personalisation of the interface
- Place screen items on the users scan line
- Use Arial (or a recognised font) in no more than 3 different font sizes
- Use redundancy (5 +/- 2 colours and shapes)
- Task must be able to be completed using a series of short glances.

Each of these heuristics is elaborated below with examples from a demonstrator interface built by Holden Innovation to demonstrate the application of each of the heuristics.

Be consistent

Consistency provides stability, making the interface familiar and predictable, as casual differences require greater user effort to understand the essential message of the display. Screens should have a consistent structure which is evident to users, allowing them to transfer existing knowledge to new tasks, learn new things more rapidly, and focus more on tasks because they need not spend time trying to remember the differences in interaction.

An emphasis should be placed upon using the same conventions and rules for all elements of the HMI. Use of colour and visual means, terms used in communication, windows and labels for input and output and changes in the system should all be consistent and not alter the way the system is operated. Functions which are similar should operate in the same way and labelling of items should be undertaken in a uniform way to prevent confusion. Consistency must be adhered to when designing for size, angles, weights and visual density of all the signs.

Misunderstandings are to be avoided wherever possible and ultimately, the HMI must have a good reason for being inconsistent. In Figure 19 and the examples that follow, it can be seen how the demonstrator interface screens were designed for consistency. Irrespective of functions being accessed, the task bar at the top is always visible. The task bar contains information such as time, passenger and driver zoned temperature indicators, clock, music input status, 'back' button and 'help' button. In addition, three core function buttons always exist down the left side of the screen and the 'go forward' button is always located at the bottom right. Therefore, the top most area and left of the screen will consistently display valuable information and provide first points of interaction with the HMI.

Temperatures always visible and in same position

Clock always visible and in same position

Music input status always visible and in same position

'Back' button always located at top left

Title bar in same location at all times

Each screen has three core function buttons

'Help' button always visible and located at top right

'Go forward' button always located at bottom right

Figure 19: Consistency of Interface

Clearly marked exit
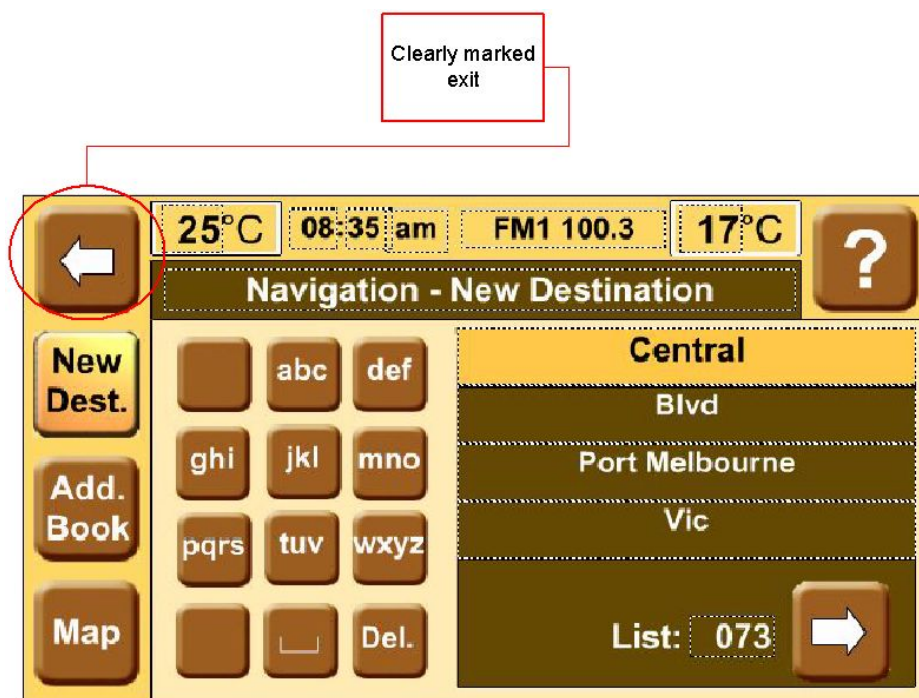
Figure 20: Exit of the Interface

Provide a clearly marked exit(s)

The HMI should have clearly marked exits to minimise or prevent any frustration the user may encounter when leaving a specific function of the system. Users often choose system

functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. In this way, the 'back' button supports 'undo' and 'redo' functions. In Figure 20, the 'back' button used in the demonstrator interface is always at the top left of the screen.

Provide Assistance

The system should offer a help menu or outlet for the user such that difficulties with the system are easy to overcome and support the performance of task function. It is better if the system can be used without documentation, however it may be necessary to provide it. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large. In Figure 21, the demonstrator interface offers a 'help' button which directs the user to a context sensitive guide with step by step instructions directing the completion of any function.
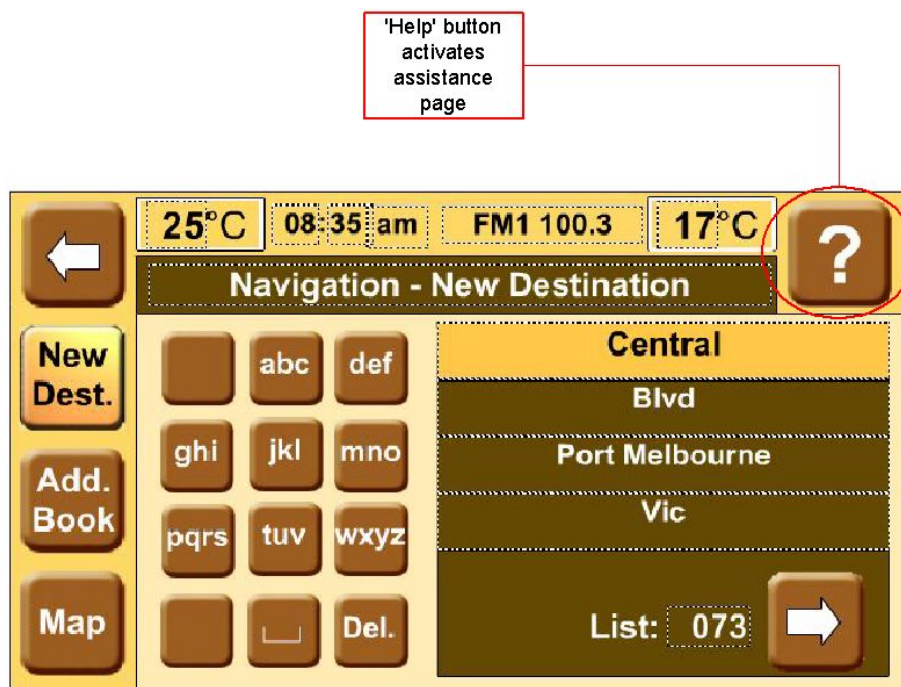
Figure 21: Assistance for the Interface

Present information in an expected display format (know the user)

A user's understanding of the communication being presented by the HMI can be greatly reduced if the language used and the display format of the system are different to that of the user's expectations. Meeting this heuristic is essential and must reflect the information gained from performing a user analysis.

A user's actions should cause the results the user expects. To meet those expectations the designer must understand the users tasks, goals and mental model. The HMI should build on user's prior knowledge, especially knowledge gained from experience in the real world. The system should speak the users' language, with words, phrases and concepts that are familiar rather than system-oriented terms. Familiarity is therefore an appeal to a users knowledge base. A small amount of knowledge, used consistently throughout an interface, can empower the user to accomplish a large number of tasks. Concepts and techniques can

be learned once and then applied in a variety of situations. If real-world conventions are followed, information will appear in a natural and logical order.

It should also be noted that matching the HMI to users expectations and task experience rather than forcing them to understand new principles, tasks and techniques also aligns with the heuristic of consistency.

The target demographic for the vehicle is used to generate a customer profile that is used to influence the HMI design. It was revealed that the likely customer for the vehicle would be university educated, 30-44 years of age and preoccupied with ingenuity and technology. From a design perspective, recognisable icons, such as a question mark for 'help', a left facing arrow for 'back' and a numeric keypad with letters for entering alphanumeric details. It was reasoned that these symbols and modes of input would be familiar to the user as they would have been exposed to them through computer and/or mobile phone use. These influences may be seen in Figure 22. For an older customer, a more conventional keyboard layout may be more familiar and easier to use. The ability for the driver to choose their preferred layout would be most desirable.
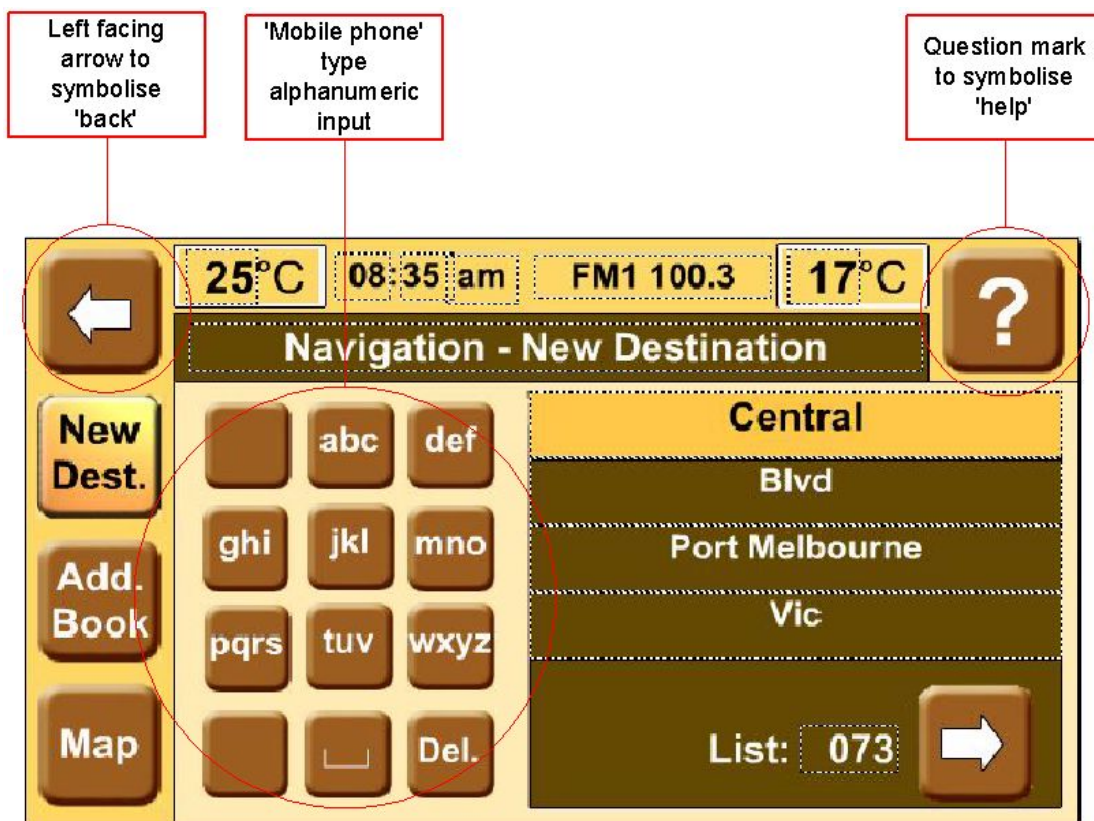
Figure 22: Knowing the User

Minimise the memory load on the user

Humans are much better at recognition than recall. Objects, actions, and options on the interface must be explicitly visible. The user should not have to remember information from one part of the interface to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate. The best way to avoid overloading the user's memory is to utilise minimalist design principles.

Only necessary and immediately usable data should be displayed to the user – no extraneous text or graphics. Dialogues should not contain information which is irrelevant or rarely needed. Clear images should be presented as poor exhibition of an image can lead to trouble with users interpreting the message clearly.

When designing the demonstrator interface, a functionality tree was generated after the requirements specification was completed. This tree scoped out the number of levels that the screens would delve into based on the desired function to be used. At all stages, emphasis was placed on minimising the amount of levels to be progressed through and ensuring that no information was required for recall to complete a function.

The user must always know what is happening, feel in control and control the pace of the interaction

Good design means configuring items so that it is evident what a person is supposed to do. Interaction between the human and the system should be natural and simple with users feeling in control of the system, not feeling controlled by it. This is ensured by allowing users to play an active role and initiate action. Linking actions with user perceptions empowers them to maintain an understanding of the context in which a task is being performed (i.e. how they got to where they were). User's choices must not be artificially restricted.

Users must always be provided with feedback for their actions. Visual (sometimes audio) cues should be presented with every user interaction to confirm that the interface is responding to the users input. Effective feedback is timely and is presented as close to the user's point of interaction as possible. A 'dead screen' is disconcerting and typical users will not tolerate more than a few seconds of an unresponsive interface. The provision of instantaneous feedback can help prevent errors. Furthermore, the sooner the feedback is given, the easier it is to determine if an error has been made or not.

The driver's pace of interaction with the system will depend on the driver's workload, and there will often be long pauses during the completion of a task. The system should not time out, or in any other way attempt to control the pace of interaction.

The demonstrator interface was designed to ensure the user felt in control, was aware of what they were doing and controlled how quickly or slowly they progressed. For example, the function buttons on the left side provide an initial focus for the users attention. From this point, each screen's title bar indicates where the user is and their attention is directed to the appropriate information in the main viewing area. The user can advance forward or go backwards at any time using the 'next step' button in the lower right hand corner, or the 'back' button in the top left. Button presses are indicated by a visual 'flash' of the button or a beep to indicate a response and any interaction will provide either a screen change of one of these button 'flashes' such that the screens never remain dormant. Figure 23 demonstrates some of these guidelines in practice.

Information should be grouped according to task, function and sequence principles

Data items on a screen should be grouped on the basis of some logical principle (e.g., task, system, function, sequence) based on user requirements. Some principles to consider are:
- Group related elements.
- Use an underlying layout grid.
- Standardise the screen layout.
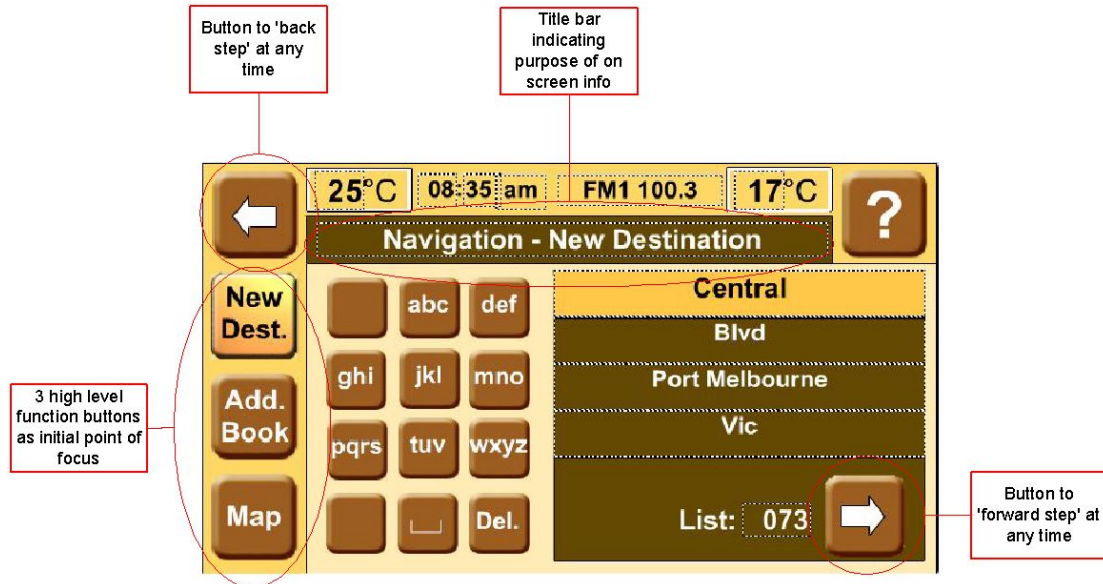
Figure 23: User Control and the Interface

Figure 24: Grouped functions and tasks in the interface

- Order and Chaos - visual and cognitive organisation prevent chaos and allow for easy learning and use.
- Visual Relationships - establish clear relationships by linking related elements and disassociating unrelated elements through their size, shape, colour etc.

- Controls, displays and information elements that are used together should be near each other.
- Often used functions should be accessible with a single button click or operation

In the demonstrator interface, the touch screen is paired with corresponding hard buttons for system selection and Heating Ventilation & Air Conditioning (HVAC) controls. These are grouped and placed based on the customer profile - graphical indicators were used for the HVAC buttons, consistent with industry practice and likely familiarity to the user. As can be seen in
Figure **24**, HVAC buttons were located in lower area together and the 6 HMI system select buttons grouped together and positioned directly below interface.

Allow for personalisation of the interface

Despite specific functions of operation being performed by the interface, variation for users' needs or preferences should be accounted for. Customisations of the system should be available to match different user preferences.

Users should be allowed to customise. The interface should be tailored to individual users needs and desires. In an environment where multiple users are sharing a machine, allow the users to create their own system personality and make it easy to reset the system (fonts, colour etc need to be changeable).

The tailoring of the interface should be limited to avoid users contravening good driver distraction avoidance principles. It is recommended that manufacturers offer 'skinable' interfaces that abide by the HMI guidelines, yet allow for differences in colour, font and layout. For example, an alternate interface offered in the demonstrator interface may be seen in Figure 25.

Figure 25: A different 'skin' for the Interface

Place screen items on the users scan line

Generally, users scan a screen in the same way they would scan a page in a magazine, which for western consumers is top left corner to the right and reading down the screen. Unlike a book, an HMI has no lines to guide the user, so users usually only do 2 or 3 incomplete scans of the screen as shown in Figure 26:
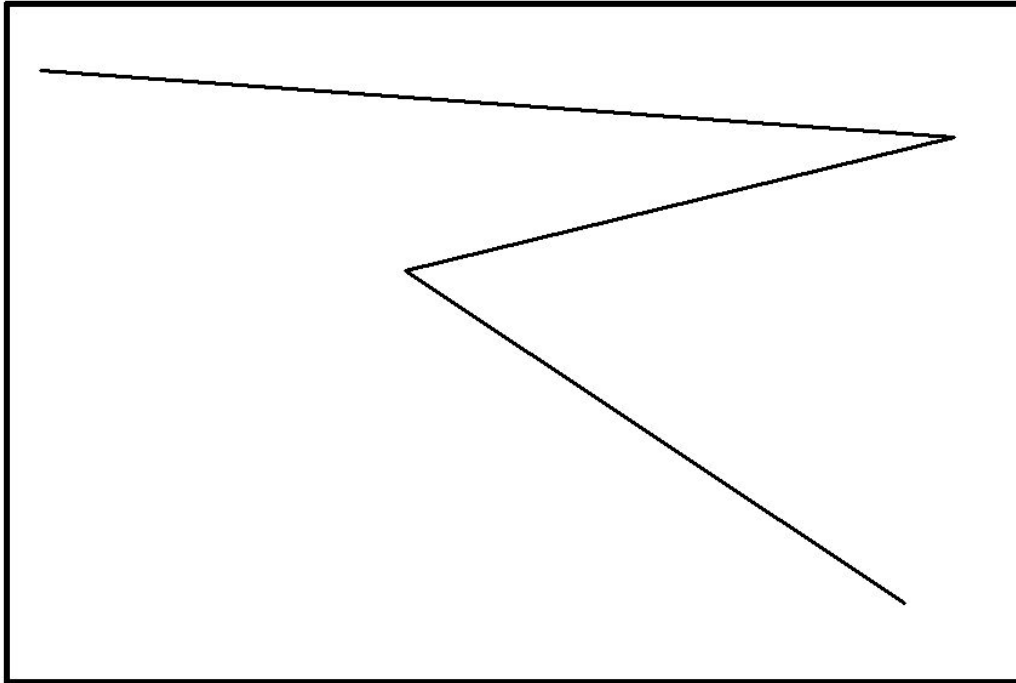
Figure 26: Scan Line of a User
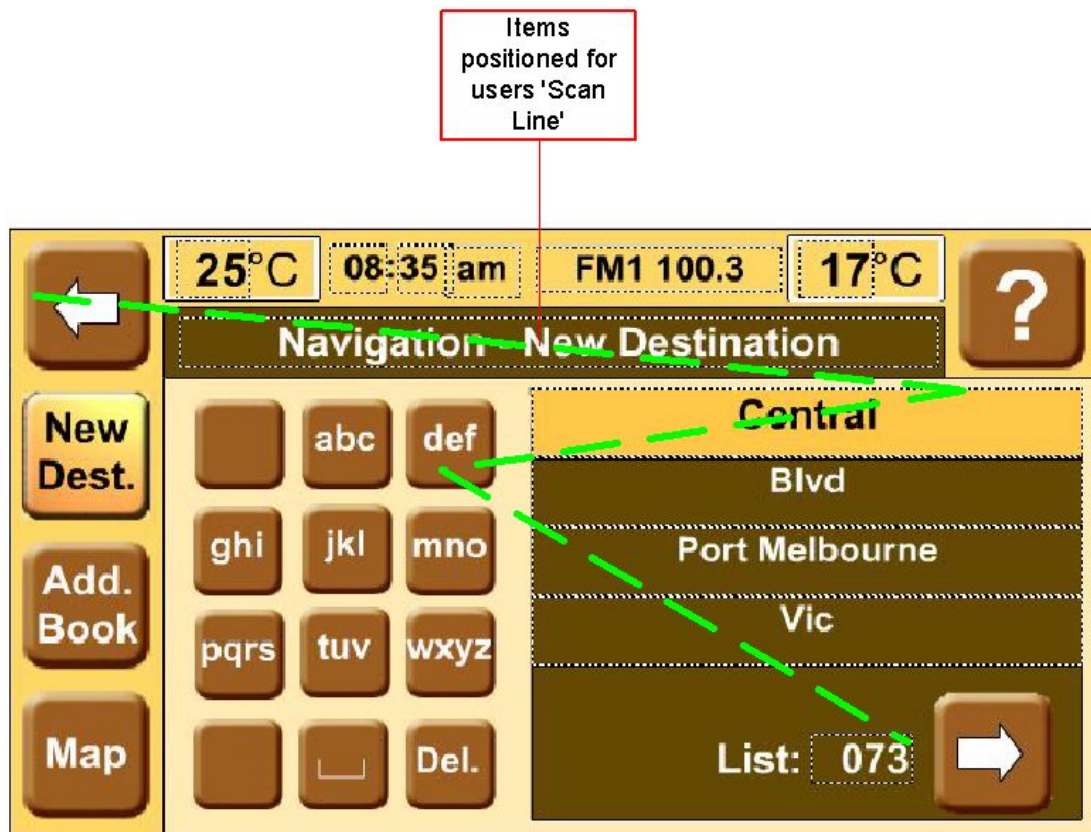
Figure 27: Scan Line in practice

Therefore, important items should be on the 'scan' line. Alarms/alerts should be placed across the top of the page, key data in centre right and buttons and controls on the lower right. Supporting graphics are better placed on the lower left of the screen. Figure 27 demonstrates how function items were placed on the HMI for the demonstrator interface.

Use Arial (or a recognised font) in no more than 3 different font sizes

A common font that exists on technological devices (for example Arial, Helvetica or System) to which a likely user has been exposed to should be used. Unexpected gothic script in operator displays is rarely appreciated. It is better to use a San-Serif font such as Arial because screen resolutions cannot clearly render the detail of a Serif font (as used in books and newsletters to guide the eye to the next letter).

Fonts must be sized correctly - it should be possible to read key information at a reasonable in car distance without the need for glasses. Arial at 16 point is a good start. The use of different fonts should be avoided and no more than 3 different font sizes used. The excess use of uppercase and underlines can be difficult to read and should be avoided. When upper case is used it should be reserved for headings. Text should be lower case with the first letter of a leading word a capital. The use of a black outline significantly enhances the sharpness of an image and should be used to highlight objects.

Figure 28 demonstrates how the font heuristics were utilised in Holden's demonstrator vehicle's interface.
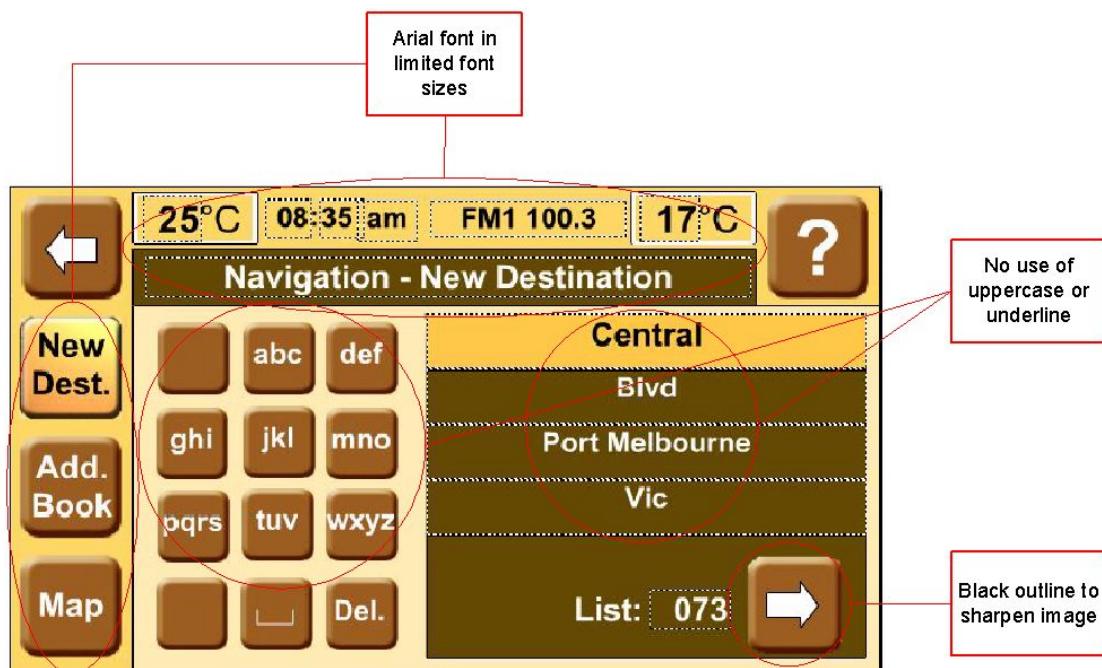
Figure 28: Arial font use and the Interface

Use redundancy (5 +/- 2 colours and shapes)

Limiting the amount of colour and shape bombardment for the user ensures that elements of the HMI where meaning is conveyed will have a greater likelihood of being remembered. Colour and shape can be used to group controls and represent their function but should be

used conservatively, conventionally and consistently. By minimising the use of colour and shapes, it is also possible to make items of focus more distinct.

In Figure 29, the use of redundancy is clear. Colour use has been limited to black, white, and 3 shades of tan. Aside from the alphanumeric variables, the shapes used are either varying sized rectangles or squares with rounded edges.
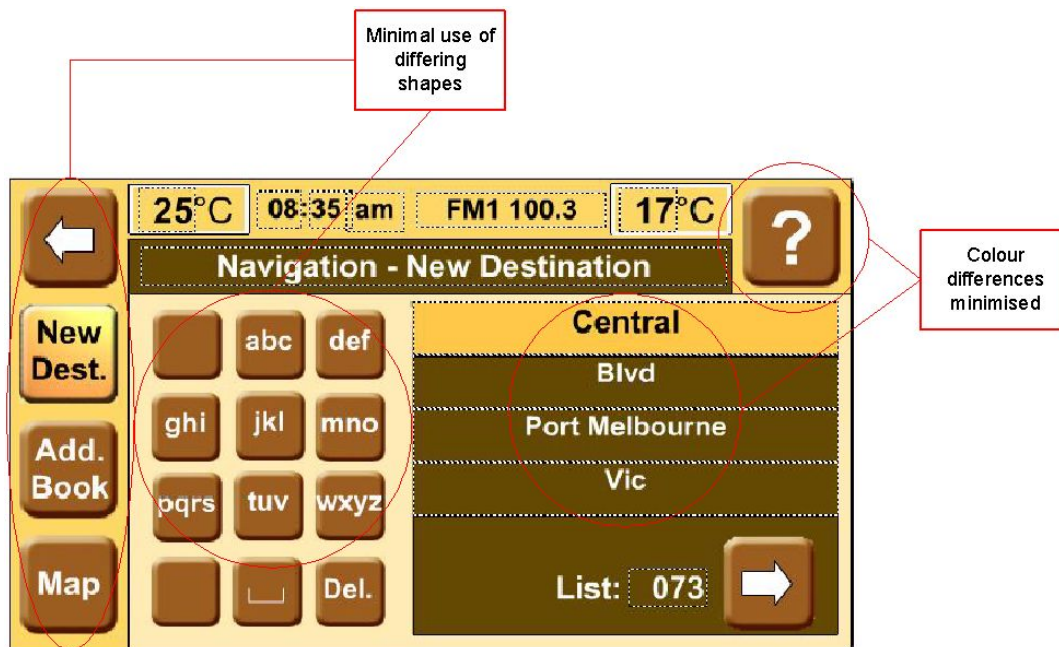
Figure 29: Redundancy and the Interface

The task must be able to be completed using a series of short glances

Visually displayed information should be such that the driver can assimilate it and/or complete a task with a few glances, which are brief enough not to adversely affect driving. For this to occur, displayed screen images must be easily understood in a short time. Ultimately, operations that occur most often or have the greatest impact on driving safety should be the easiest to perform.

For a task to be completed safely while the vehicle is in motion, it must be "chunkable", that is, the task can be completed in a series of glances, each glance no more than 2 seconds duration.

The Standards

The increasing demand that in-vehicle information systems place on driver's attention has been recognised internationally. In the past 3-4 years Europe, the US and Japan have all issued standards or guidelines. Although similar in their aims, each is different in its execution or recommendations.

Japan

The Japanese standard – JAMA (Japan Automobile Manufacturers Association) is very prescriptive about the design of the system. It prescribes the content of information to be displayed, method of display system operation, and location of display systems with the aim of fully utilising the beneficial functions of in-vehicle display systems, while allowing the defensive behaviours of drivers.

The standard focuses on the following areas (Japan Automobile Manufacturers Association, 2004):
- Installation of display systems
- Installation positions of display systems
- Installation positions of display monitors
- Functions of display systems
- General display function
- Display content of visual information
- Presentation of auditory information
- Display system operation while vehicle in motion
- The presentation of information to users

Examples from the JAMA standards (Japan Automobile Manufacturers Association, 2004):
- The number of letters displayed at a time shall not exceed 31, provided that a number such as "120" or a unit such as "km/h" is deemed to be a single letter irrespective of the number of digits. Punctuation marks are not included in the count of letters.
- Maps being displayed for navigation purposes shall not show minor roads in urban areas. However, if the indication of such roads causes the driver neither to gaze continuously at not look for shortcut routes on the screen, minor roads in urban areas may be shown in navigation maps of the following conditions:
- Those minor roads deemed important in the entire network of roads may be shown
- In maps more detailed than a 1:20,000 scale, minor roads may be shown only while running on narrow roads. However, when the map on the screen is manually scrolled (including improved and simplified scrolling options), minor roads shall not be shown.
- In maps of a 1:5,000 or more detailed scale, minor roads may be shown while the vehicle is in motion. However, when the map on the screen is manually scrolled (including improved and simplified scrolling operations), minor roads shall not be shown.
- The display of navigation maps shall be prohibited if the driver is confused when the maps are automatically scrolled in keeping with the speed of the vehicle.

Europe

The European and American standards are very similar and focus mainly on design principles. The EU Commission Recommendation on safe and efficient in-vehicle information and communication systems: *"A European statement of principles on human machine interface"* (Official Journal of European Communities, 1999) summarises essential safety aspects to be taken into account for the human machine interface (HMI) for in-vehicle information and communication systems.

The recommendations are broken down into the following areas:
- Overall design principles

- Installation principles
- Information presentation principles
- Principles on interaction with displays and controls
- System behaviour principles
- Principles on information about the system

America

The National Highway Traffic Safety Administration's (NHTSA) statement of principles was developed by America's Alliance of Automobile manufacturers (AAM). This document of recommendation is made up of 24 principles and focuses on the following areas (Driver focus-telematics working group, 2002):

- Installation Principles
- System location recommendations
- Information Presentation principles
- Use of icons, images and symbols
- Information presentation
- Principles on Interaction with Displays and controls
- System Behaviour Principles
- Lock out of features
- Principles on information about the system
- Instructions, Product information, safety instructions etc

United Kingdom

The United Kingdom has developed its own standard, the Transport Research Laboratory (TRL) – *A safety check list for the assessment of in-vehicle information systems: A user's manual.* This document is designed to be used as an assessment tool. The checklist rates different tasks on how much of a risk they present to the driver and other drivers on the road, and makes recommendations for each point. It focuses on (Stevens, Board, Allen, Quimby):

- Documentation
- Installation and integration
- Driver input controls
- Auditory properties
- Visual properties of the display and display screen
- Dialogue between user and system

Australian Standards

The Australian car industry needs to work together to produce standards applicable to this country. Low volume production runs mean that without a common local standard, Australia is destined to accept often inappropriate and mediocre "off the shelf" interfaces from overseas.

Low volume production runs mean that individually, Australian automotive manufacturers may not be able to support the many millions of dollars of investment typically needed to customise the design of navigation or information systems.

If the whole industry supported a local standard, then the collective volume of the Australian market would be sufficient to cause suppliers to customise their designs to conform to the standard.

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Photo courtesy Mercedes Australia

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Photo courtesy Citroen Australia

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PRESENTATION SLIDES

Today's Driver Interfaces

- Holden

Direction arrows for menu navigation

Centrally mounted colour screen

Remote Control

Future Trends

- The next wave of change
  - Vehicles will become fully connected to the internet via Telematics.
  - It is estimated that by 2006 there will be 46 million vehicles with Telematics worldwide with subscriber revenues totalling US$8 billion.
- There is strong consumer demand for location based services
  - Traffic information
  - Emergency callout
  - Fuel and Parking
- USA
  - GM: Telematics standard fitment on all cars by 2007.
- Australia
  - Approx. 7,000 cars with OEM Telematics
  - Growth rate of 118% per year.

The Trends

- AT Signature Project
  - Systems are real
    - Fitted to an on road car
  - Today's technology
    - Will be available soon for incorporation into Australian cars

- The trends cannot be ignored nor legislated against
  - Imported cars will have these features
  - Locally made cars for export must have these features
  - Local standards must be in harmony with global standards

The People

- The human element of the driver distraction issue is complex

- Cognitive and sensory capabilities differ greatly due to:
  - Age
  - Experience
  - Training

- There is much ongoing research in this area
  - Holden & MUARC (Monash University Accident Research Centre)
  - Other automotive R&D centres globally

The People

• Age

- Older drivers deviate more with speed and lane position than younger drivers when using a mobile phone

- The risk of being involved in a crash from in-vehicle distractions increases with driver age

- Despite these findings older drivers are not over represented in fatal and serious injury crashes

- Older drivers are less willing to perform distracting tasks whilst driving than younger drivers

- Drivers between 25-29 are most likely to be involved in a crash when using a hand-held mobile phone
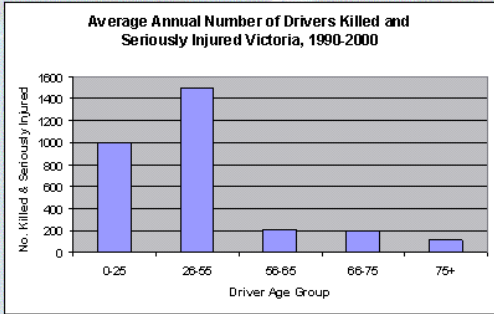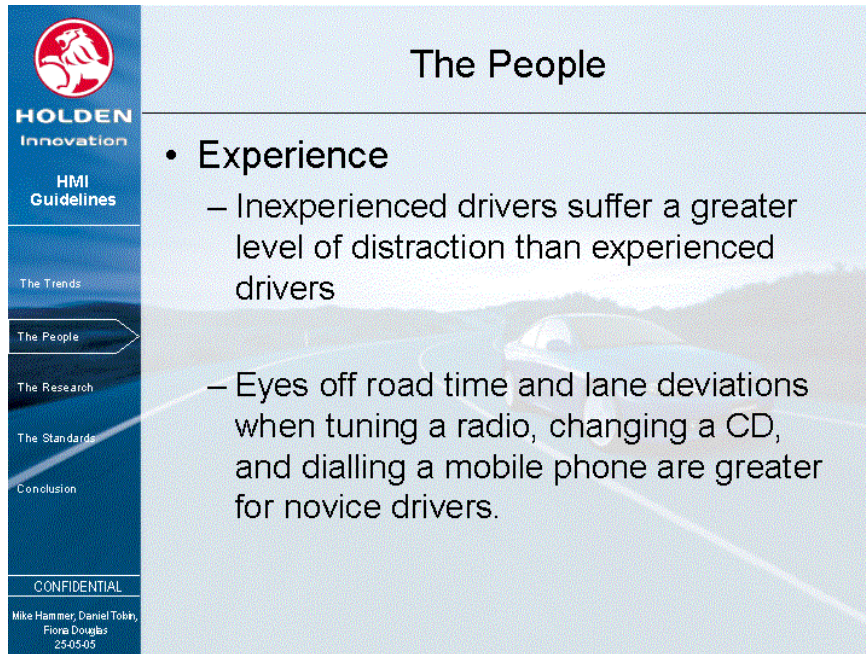
The People

• Age

- Young novice drivers represent only a minor proportion of the licensed population (14% in Victoria in 2002)

- Four times more likely to be involved in road crashes, fatalities and injuries than older, more experienced drivers

- More likely to engage in distracting activities

Types of Distraction

- **Mobile Phones**
  - Using a hands free phone while driving is no safer than a hand held phone
- **Navigation Systems**
  - A well designed turn by turn navigation system is less distracting than using a paper map
- **Entertainment systems**
  - Changing a CD is one of the most distracting tasks a driver can perform

HOLDEN Innovation
HMI Guidelines
The Trends
The People
The Research
The Standards
Conclusion
CONFIDENTIAL
Mike Hammer, Daniel Tobin, Fiona Douglas
25-05-05

Holden & MUARC Testing

- **Ease of Use:**
  - A range of luxury cars with different types of user interface
  - 5 tasks to perform with vehicle stationary, then while driving:
    - Set temperature & vent to re-circ.
    - Manually tune radio and store
    - Enter home address into navigation system and start guidance
    - Insert CD and select track 5
    - Phone someone and leave a message

HOLDEN Innovation
HMI Guidelines
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25-05-05

Holden & MUARC Testing

• Ease of Use:

– Some participants completed tasks easily
– Others could not complete the tasks within the 45 minutes, even with the vehicle stationary.
  • An interface may be intuitive to one person, but completely unusable for another.

– Many of the older participants would not attempt the more complex tasks with the vehicle in motion.
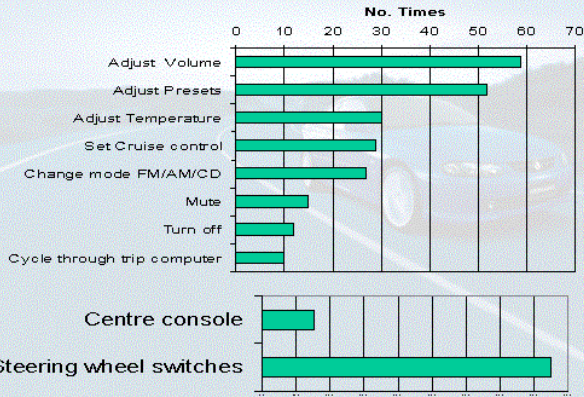
Holden & MUARC Testing

• Most Used Features & Input Modes
  – Log kept by 6 participants over a 4 day period