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ARE WE THERE YET?
THOUGHTS ON IN-CAR HMI

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Produced by ustwo
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FIVE PART BLOG

With the ongoing integration of advanced computer systems into vehicles, the interfaces within are becoming ever-more complex.

As the prime points of interaction between driver and car, these 'human–machine interfaces' (HMI) demand great care and attention from manufacturers, designers and engineers alike.

ustwo wrote a blog series focussing on this subject, posting one part each day for five days. In this five part thought series we looked into this phenomenon of growing in-car HMI complexity. We explored our belief that an interface should match the evocative nature and elegance of an automobile's exterior and interior design. We also outlined our key thoughts on how, in partnership with manufacturers, we can bring an extra layer of care into the design of compelling experiences, in order to tame the beast that is in-car HMI.

We touched upon interaction patterns (covering issues with muscle memory and regulations), took a qualitative look at current on-screen interaction and visual design, briefly gazed into what the near future might look like (we see haptic and aural feedback), and finally said a few words about our own approach to in-car HMI design here at ustwo studio.

This eBook consolidates the series into once designed, considered document which is optimised for both desktop and iPad viewing.

From all of us at ustwo, we hope you enjoy it.

THE AUTHORS

Tim Smith

Visual Design
& UI perspective

@mypoorbrain

Tim is a design specialist at ustwo with ten years of visual design experience and 14 awards and honours to his name (although 13 of those awards were made up by himself).

Tim is known for his illustration work and ability to expertly translate brand into interactive digital experience designs.

His client experience includes Sony PlayStation, Amex and Evian. Tim's current area channelling his OCD is fitness and diet, where he is undergoing a regime so strict, that he forbids himself to be within 50 metres of any unhealthy food.

Harsha Vardhan

Interaction &
UX perspective

@wabisabifiction

Harsha is an interaction and service designer with a background in industrial design and engineering. He is a graduate from the Copenhagen Institute of Interaction design (CIID) and the Indian Institute of Technology (IIT), Delhi.

During his time at the CIID consultancy he worked with Toyota's Kansei division.

Between 2012-13, Harsha worked at Service Innovation Labs in Berlin, solving urban mobility issues (which included parking and car-sharing) for two of Germany's largest car manufacturers. Since joining ustwo in late 2013, he has been saving up for a BMW F800 on ustwo's save and match scheme.

Barnaby Malet

Developer
perspective

@barnabymalet

Barnaby started building for the web in 2006 and hasn’t stopped since. He graduated from Imperial College with a masters in computer science before pursuing a PhD in distributed systems.

After 12 months he realised that it wasn’t for him and headed to startup land. He now spends his time writing JavaScript, Ruby and Objective C. He has a passion for cutting edge technology and product development driven by solid user feedback and analytics. At social events he avoids bottled lager and instead prefers to go home to get an early night.

David Mingay

Process & petrol head perspective

@dmingay

David has over 15 years experience in digital design, spanning a wealth of industry verticals, engagement types and user touch-points. After graduating from Northumbria University with a design for industry degree, he immediately jumped into the digital world of set-top boxes, CD-ROMS and kiosk design.

Before long, the interweb appeared and David became involved in all things web related, including branding and user experience design, Flash programming and animation. Now at ustwo, he prides himself in being the 3rd oldest person in the company, with the greyest beard. ■

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THE NEAR FUTURE OF IN-CAR HMI

INTRODUCTION

Which consumer technology market has changed and advanced most in the past decade? It has to be the mobile phone sector.

Thanks to game-changing user experiences delivered through touchscreens the market has rapidly evolved, giving rise to tablets, phablets and the like. Along with advances in chip, display and web-based technologies, mobile devices have become more and more affordable, achieving unprecedented mass adoption. It seems only natural that they have found their way into the cars we drive today, replacing physical buttons and knobs with pixels.

There is much potential for in-car HMI, but we have yet to see a similar revolution in the UX and UI of the automotive industry.

A recent survey by software supplier Cisco Systems suggests that the automotive industry is not meeting consumer demand in respect of technology. In order to bring in-car HMI up to speed, the industry needs to gear up.

“Cars are the biggest and oldest mobile devices… the face of mobility. We’ve [Ford] been around for over a century. But we welcome the competition from newcomers like Apple and Samsung.

Paraphrasing John Ellis (Head of Ford’s developer program) at CES 2013

HTC car stereo clip

Pervasive and distributed computing, affordable and accurate sensors for measuring physiological and mechanical systems, and the notion of networked objects (the Internet of Things) all play a part — and all are available through smartphones.

And therein lies the challenge: as people become ever more dependent on their smart devices, they begin to expect more of embedded technology elsewhere in their lives. Sadly, these expectations are not being met by the current generation of in-car HMI.

Furthermore, patterns of ownership have changed. The young urban populace is moving away from car ownership and towards 'pay as you go' or car-sharing schemes, throwing up all kinds of new design considerations.

However, in the haste to get on-trend, car manufacturers have simply used screens to replicate what has been before, rather than taking an empathetic, intelligent approach. Skeuomorphism abounds, where physical buttons are replaced with lookalikes on a screen —

familiarity is retained, but at the expense of tactile feedback. Current touchscreen HMIs are often simply ill-considered re-appropriated solutions developed for completely different contexts (which we will discuss later).

We believe that there is a need to approach this topic anew, in light of these challenges and others we will highlight later on in this series.

ustwo is a design studio specialising in the creation of digital products and services across multiple technological platforms. When it comes to in-car HMI, we've been learning and adapting as we go — finding our feet and getting stuck in. Our experience in meaningfully connecting people and technology, through the rapid prototyping and testing of conceptual ideas gives us a solid base from which to challenge the status quo.

In this series we focus on recognising the issues, exploring the opportunities and offering solutions for in-car HMI. We also describe the approach we took in developing our own concepts for the in-car experience when working with one of the world's leading automotive manufacturers. ■

^
Tesla vs the Boeing 757-300:
a comparison where screens abound, but in the aircraft cockpit, physicality remains. This says a lot about the 'learnability of purely screen-based controls such as those seen in the Tesla's centre console.

LOOKING BACK:

WHERE WE ARE NOW & WHERE WE WERE

ORGANISATIONAL & LEGACY ISSUES

Photo credit: thecarscoop.blogspot.com

The velocity of growth in digital technology and its adoption has not been matched by automotive manufacturers.

Although expert in the design and build of highly functional and emotional hardware, automotive manufacturers often ignore the critical interactions and opportunities between car hardware and HMI.

This is generally due to home-grown complexities — long cycles of engineering and manufacture continually put them behind the curve of computational evolution (Moore's Law does not apply to large scale manufacturing and materials sciences).

Another roadblock is the siloed team structure within manufacturing industries, where engineering is often isolated from interior UI and interaction design teams.

When working with organisations that have this structure, we've experienced a narrowing approach to problem solving and opportunities. As a result, cutting-edge technology is not used to its best advantage and the basic theories underlying cognition and human–machine interaction are not fully applied.

Samsung “smart fridge”
with embedded touchscreen

“ And today we are adding the digital user interface. The two large monitors in the new S-Class, each measuring 12.3 inches, currently represent a benchmark.

Designer interview on the Mercedes Benz website

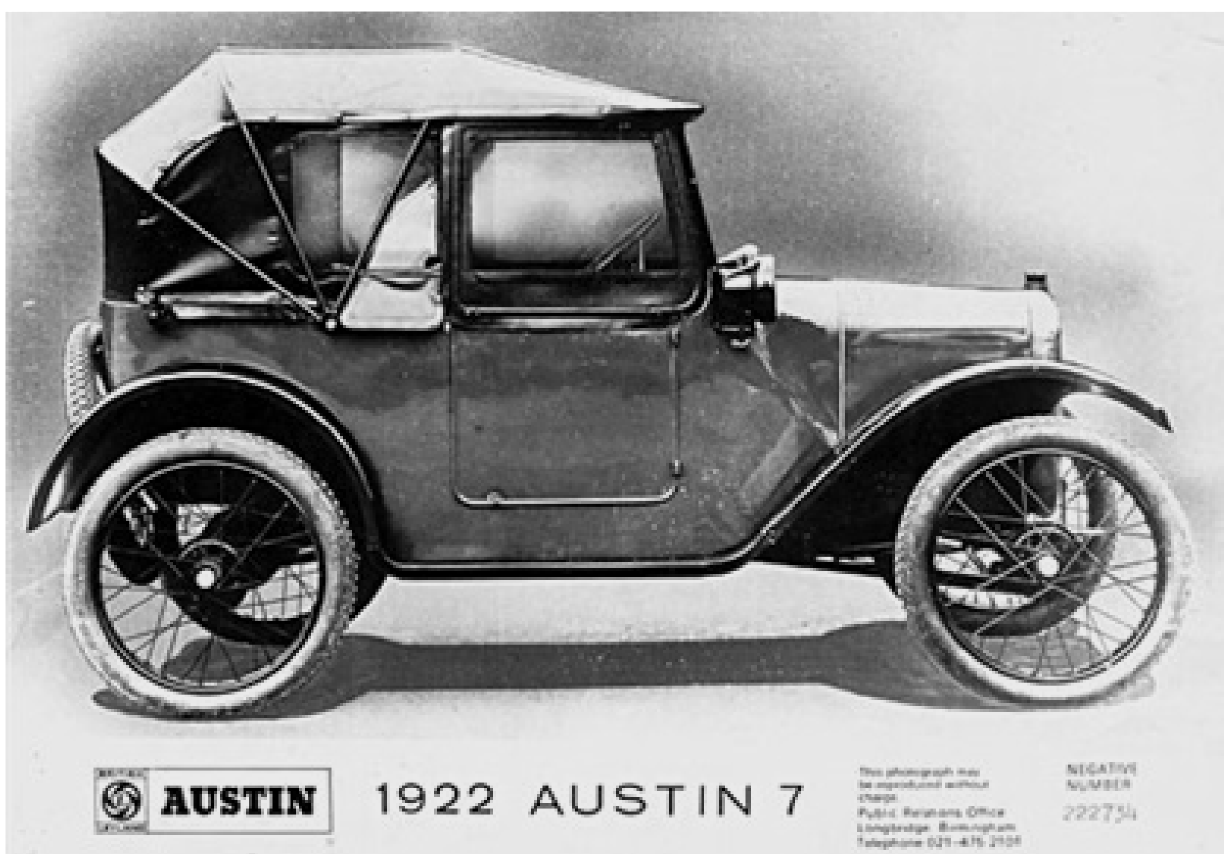
Even when teams do work together, it is often too late to share disruptive product and experience ideas. This is evidenced by the ‘stick a touchscreen on it’ phenomenon, seen on many appliances and in-car interfaces.

The motor industry also tends to rely on a ‘couture’ methodology for car design, whereby very high level concepts are brought to life, with the aim of wowing motor show attendees. In order to get some semblance of the concept into an actual production vehicle, designers have to ‘over-egg’ the idea in anticipation of its dilution.

This approach, although effective, does not suit concepts that require a high degree of user interaction with new technology. This is because in order to get these experiences right, you need to develop the user experience with real users, in near-real situations. We believe that a methodology is needed that allows concept, user experience and user interface ideas to be developed in a collaborative and effective manner. We will cover this in detail later in this series.

COGNITION & MUSCLE MEMORY ISSUES

1922 Austin Seven



The nature of driving a car has not changed since the Austin 7 of the early 1920's.

The archetypical automobile, with its specific driving position, steering and control scheme, gauges and even its reliance on the internal combustion engine has not really taken any major evolutionary steps in the last 80 years.

This dogged consistency has helped the automotive industry over the years — a user needs only to learn to drive one car in order to drive any car.

What has been changing significantly is the integration of electronics and, more recently computers, into the HMI (e.g. GPS, telematics, ADAS, and infotainment systems). These elements have introduced new layers of complexity to interactivity, completely changing cognitive models and expectations.

Left: Mercedes SL 1970s
Right: Mercedes SL 2013

Consider the interior of a Mercedes SL from the 1970s compared with a present day Mercedes SL.

In a typical interaction design fashion, we can break down the analysis of the past and present HMI by looking at:

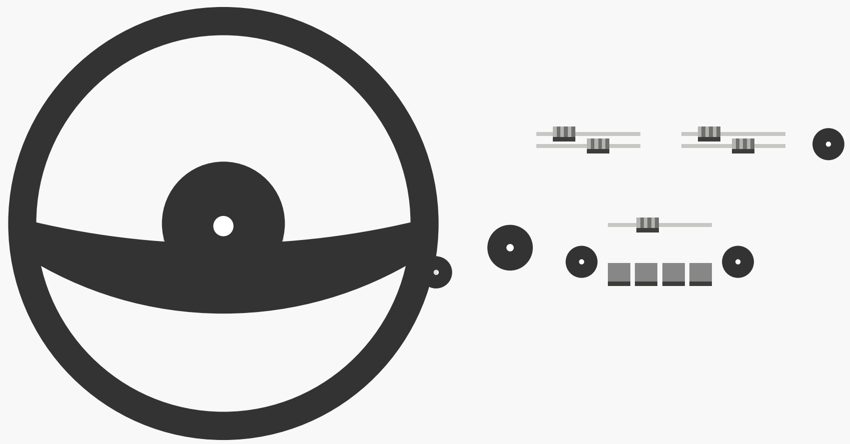
Controls: tools or devices which offer control of in-car functions (e.g. a knob on a music player). Affordance: the nature of manipulation a control offers, while performing an action (e.g. a knob can be turned about on an axis).

Feedback: the change or reaction brought about by the controller (e.g. the change in volume when the knob is turned).

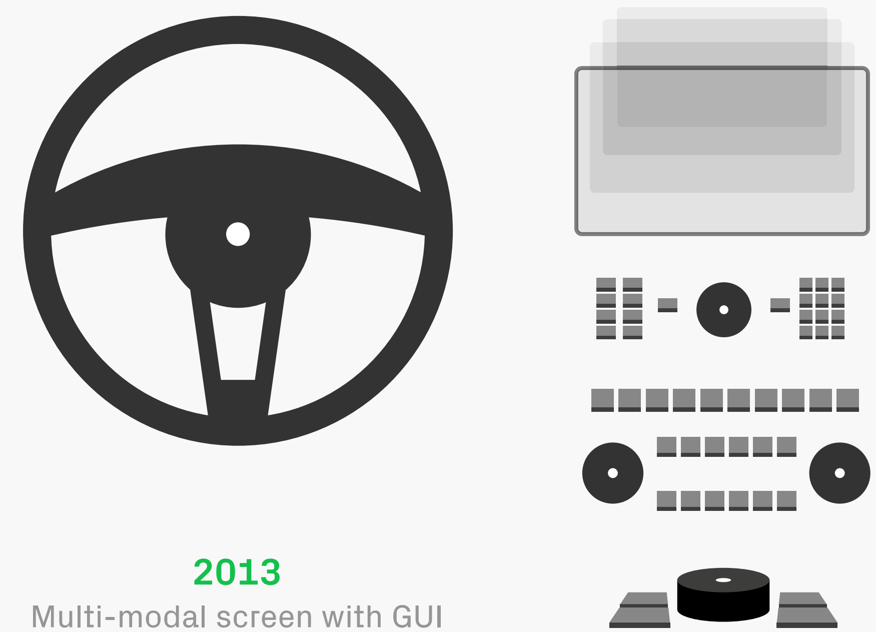
Mapping: developing a 'feel' for controls — the ability to understand what a control does and where it is located (an accomplished pianist can play the instrument blind, by 'feel' or muscle memory).

Learnability: the ability to understand the way a control behaves over time (e.g. turn the knob clockwise to increase volume).

Modes: the number of ways a tool or device can be used and repurposed by switching to a new function (e.g. the same knob can also be used to control brightness).



1970
Knobs, switches, sliders offer
direct control / manipulation



2013
Multi-modal screen with GUI
Indirect control via knobs & switches

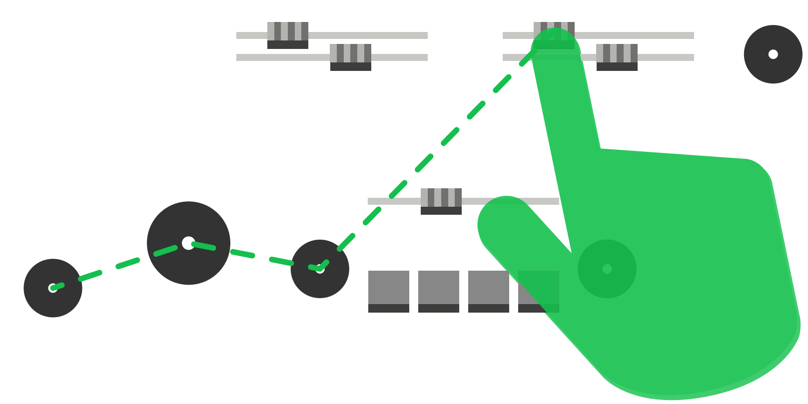
In the car interiors of yesteryear, the spatial arrangement of the dials and knobs allowed for a mental map of the HMI to be developed over time and in turn built into muscle memory.

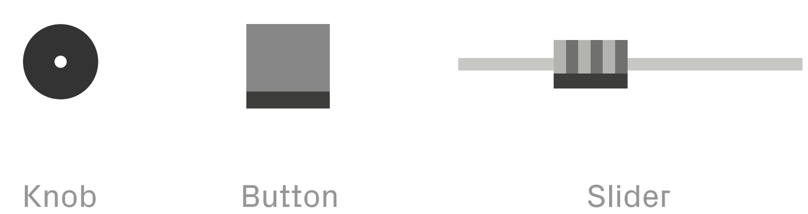
Since there were fewer electrical complexities, mechanical elements such as knobs, switches and sliders provided both control and direct mechanical feedback —a tangible user interface. There were far fewer modes, because there was direct communication between the elements on the car and the controls.

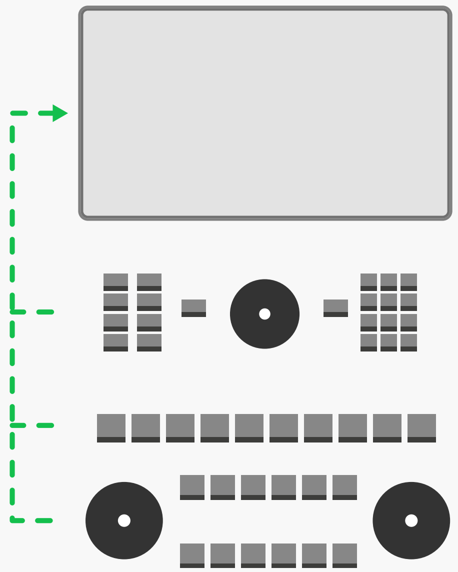
Learnability was always a factor, but a sparse set of controls meant an inherent simplicity.

With modern HMI it's a completely different story. There are many more controllable elements within cars, numbering in the hundreds—navigation systems, telematics, ride control and infotainment systems to name but a few.

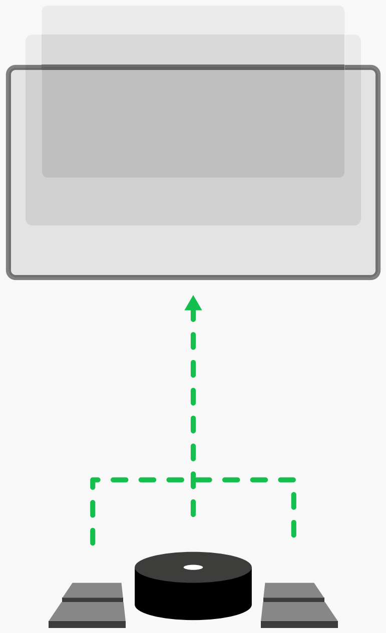
›
The spatial arrangement provides for a mental map of the controls over time



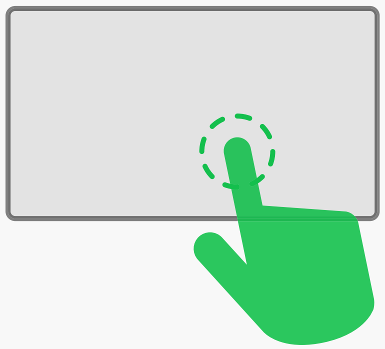




Single function controls
Calls, seat / drive position



Control knob turns through, selects
modes and operates the GUI



Touchscreen
Direct manipulation of GUI

Nowadays, there is a mix of both tangible and graphical user interfaces (GUI), with the GUI behaving as the primary source of feedback with multiple modes for different in-car functions and systems. Elements within the GUI can be controlled either indirectly via mouse-like devices or more recently, by manipulating elements via touch.

This short clip shows how the control knob indirectly controls modes and elements within the GUI of the Mercedes SL 2013.

This adds a fivefold complexity in cognition:

1. Shifting between modes: (and learning where they are) does not allow for a single mental map to be built up over time. By way of an example, see the video for how to move between sat-nav and seat position control.

2. Ease of Mapping or Learnability of the GUI: Where are the controls and what are their functions? Can they be learnt easily?

3. Affordances: how does moving a circular knob relate to movement between modes on the screen? Can we bring back the direct control seen in the cars of yesteryear?

4. Feedback: at present there is a reliance on visual feedback in the GUI which can be very distracting. Complimenting visual feedback with aural and/or haptic feedback might be the answer. (Haptic technologies are tactile feedback systems that take advantage of the sensation of touch).

5. Consistency and muscle memory: if a person changes car models or even manufacturers, they have to relearn some of the basic controls from scratch.

With the advent of these multi-modal HMIs, people are now faced with an unprecedented level of complexity, as well as the added pressures of congested driving. This plays a huge role in decision making due to the limited nature of data storage and access in the human mind.

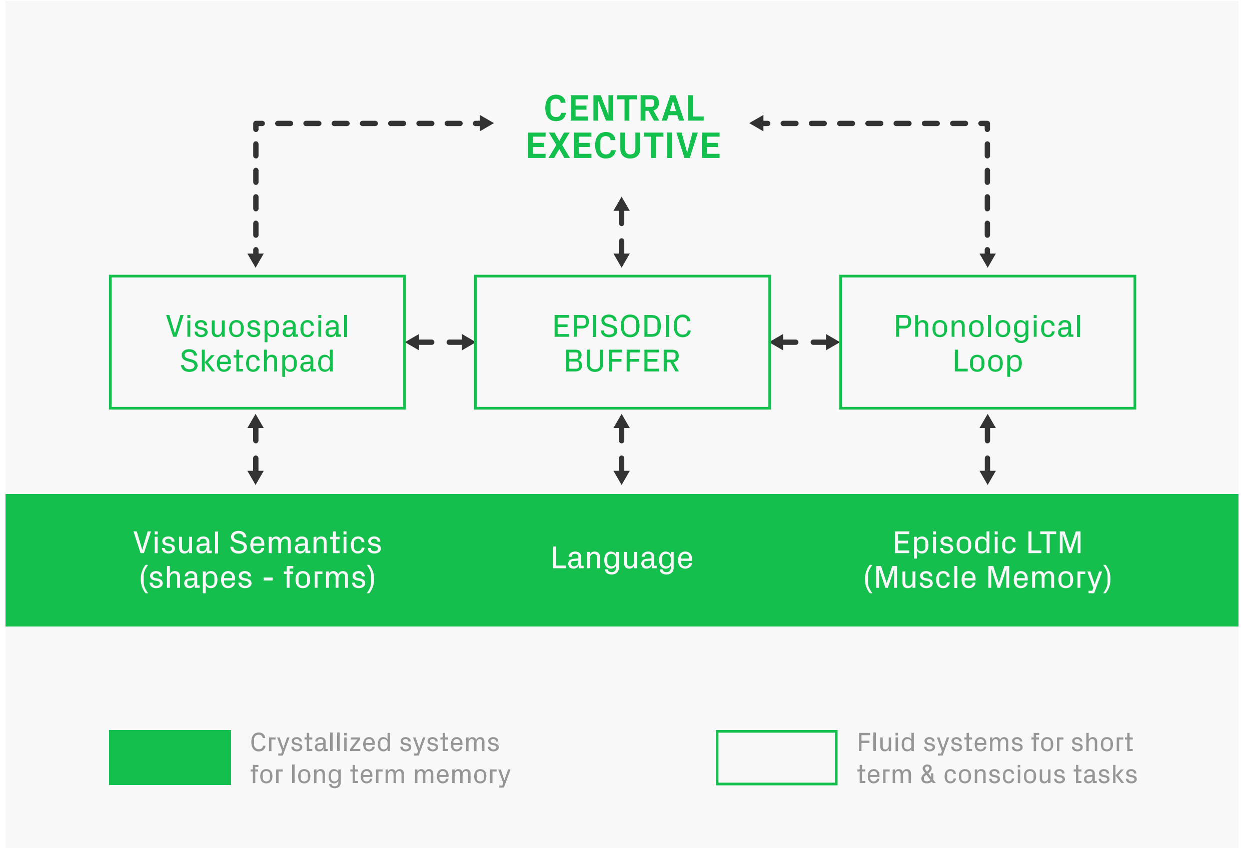
LIMITATIONS OF COGNITION & 'THE WORKING MEMORY MODEL'

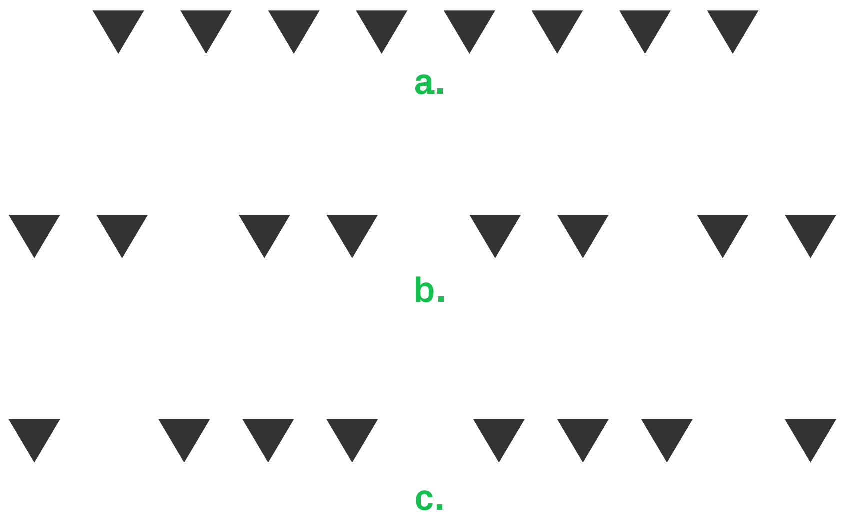
To understand the limitations of cognition, we first need to look into how people consciously engage with the world through the construction of long-term and short-term memories and their retrieval over time.

The 'Working Memory Model' put forward by Baddeley & Hitch in 2000 (first in 1974) describes the interplay between a 'crystallized' long-term memory system, a 'fluid' short-term memory system and a limited capacity 'episodic buffer'. The crystallised long-term memory system comprises language, knowledge of shapes and forms, and muscle memory, whereas fluid memory tends more to the visual and auditory.

For further information, see these related papers and talks.

The 'Working Memory Model' put forward by Baddeley & Hitch in 2000 (first in 1974)





The Gestalt principle of 'Proximity'- notice the grouping of elements in a, b & c, based on how close they are in relation to each other

> ***"** The Episodic buffer is assumed to be a limited capacity temporary storage system capable of integrating information from a variety of sources.*
>
> **Allen Baddely (2000) from 'The Episodic buffer: A new component of working memory'**

One can consider the act of driving to be crystallised, since it uses long-term muscle memory, whereas the information consumed around that task of driving — Who's walking in front of the car? Where am I driving to? What am I listening to? — can be considered to be part of a conscious experience and in the episodic buffer at any particular time.

The episodic buffer has a limited capacity for taking in visual, auditory and motor cues, so a HMI which does not allow for the easy construction of skill or muscle memory can easily overtax it. This in turn leads to bad decision-making and frustration on the part of the driver due to cognitive overload.

Over the years human–computer interaction studies have postulated several key methods for tackling the problem of cognitive overload. One such method is the concept of 'Chunking' as proposed by George Miller in 1956, whereby an individual can remember or process only seven chunks of information, in their correct serial-order, in his working memory. This essentially means that grouped items are easier to recall, because grouping assists phonological and visuospatial memory.

+445232367456

Linear

+44 (523) 2367 456

Chunked

The concept of chunking also seems to apply to visual forms, similarly grouped shapes or patterns are also easier to remember. This is known as the Gestalt principle of proximity. Further evidence for this concept is suggested in studies here.

FRUSTRATION, CONFUSION & SAFETY ISSUES

The complexities of in-car HMI, combined with the limitations of human memory may result in cognitive overload for drivers.

As a result, minimising distraction and reducing driver error has been the focus of law and policy makers worldwide. Efforts are being made to curb the use of distracting devices (eg mobile interfaces) which in turn also influences the design of HMI.

For instance, the European statement of principles on in-vehicle HMI issued by the Commission of the European Communities states:

“ The system should be designed to support the driver and should not give rise to potentially hazardous behaviour by the driver or other road users.

“ The system should be designed in such a way that the allocation of driver attention to the system displays or controls remain compatible with the attentional demand of the driving situation.

“ The system should be designed so as not to distract or visually entertain the driver.

European statement of Principles on in-vehicle HMI, Commission of the European Communities

Or the NHSTA guidelines (USA), a summary of which is present here. The guidelines are based upon a number of fundamental principles:

> *“The driver should be able to keep at least one hand on the steering wheel while performing a secondary task (both driving-related and non-driving related).*

> *“The distraction induced by any secondary task performed while driving should not exceed that associated with a baseline reference task (manual radio tuning).*

> *“Any task performed by a driver should be interruptible at any time.*

“The driver, not the system / device, should control the pace of task interactions.

“Displays should be easy for the driver to see and content presented should be easily discernible.

NHTSA Guidelines

So, it is fair to say that many of the issues we currently face in HMI design are borne of the legacy of the space and the automotive industry infrastructure. The siloed nature of design teams means that while new functions may be introduced, organisational structure might not allow for the sensitive incorporation of these features.

This leads on to learnability issues, not to mention frustration and the obvious safety concerns as put forward by regulatory agencies. Though manufacturers are definitely aware of these issues, it is our view that many of them could be mitigated early and rapidly, if a “one-team” collaborative approach was adopted, where they can design, build and test ideas with real users to learn and iterate accordingly. ■

1969 Bertone BMW
Spicup Concept

LOOKING AT THE NOW:

CHANGING PATTERNS
IN HMI

CONNECTED CARS: A LONG TERM SOLUTION?


Tim Smith
Design Specialist
ustwo


Harsha Vardhan
Interaction Designer
ustwo

In the past year we've seen Apple, Microsoft and Google enter the in-car space with their own custom HMI concepts.

The media has focused on the potential for new user experiences within the connected car and the likely emergence of a strong in-car app market.

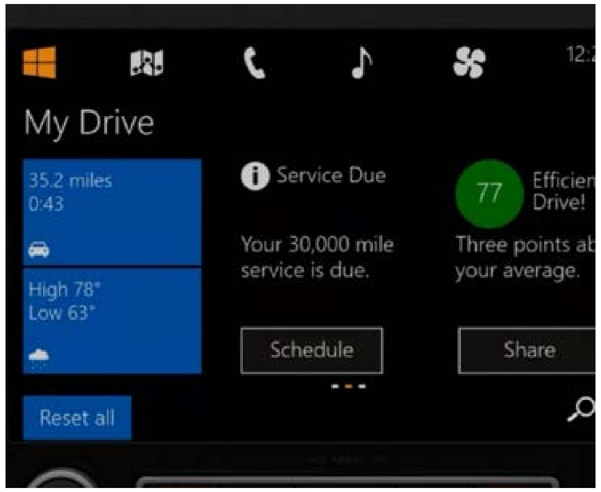
Take a look at Apple's 'Carplay' and 'Android Auto'.

The notion of a connected car has a significant impact on the way HMI is conceived and implemented.

As we see it, there are three models at present:

Model 1: The radically connected car
Such as the Tesla S, where the hardware, software and HMI is all custom-built; integrated from the ground up. This model allows the deep integration of not only the multimedia systems, but also diagnostics and control systems inside the car with the driver. Connectivity (see these tie-ups with network service providers) and an API also allow interesting custom apps and services to be built by independent developers.

Smartcar provides climate control both within the Tesla S and the home



>
Top: Apple CarPlay
Middle: Google Open Automotive Alliance
Bottom: Microsoft Window in-car

Model 2: Custom HMI modules that use software platforms like 'Microsoft Embedded Automotive 7' or Blackberry's QNX to manage and integrate different devices and sensors in a car into one platform. For example, Ford used Microsoft's platform for their relatively long running 'Ford Sync' HMI systems. In this model custom interfaces for drivers are created, which means that the status quo, fragmentation of interfaces and experiences, still remains. However, the inherent independence allows for the creation of custom experiences for users while being agnostic to the driver's mobile device.

> *“ Apple, Ford, Android and others — are targeting the car as the next frontier for mobile development.*
>
> **Adario Strange, Mashable**

Model 3: Integration of same-platform devices to onboard HMI as done by Apple and Microsoft. While this might mean less fragmentation of operating systems, the user is wedded to one platform both in-car and in everyday life if they want everything to integrate.

So which model of connected car is best?

Model 3, while exciting, is borne of different motives to Models 1 and 2. Apple, Google, Microsoft et al are all looking for a gap in the market or, more precisely, an extra touch point in which to sell more devices. The design community may well be all fired up designing apps for cars, but what are the potential pitfalls of an app-based approach?

First and foremost, drivers are beholden to a hardware/software manufacturer. To make Apple CarPlay work on the Mercedes Benz C-class, the driver has to plug in their iPhone. Similarly, to use 'Auto' you'll need an Android phone.

Will people start to choose cars based on their handset of choice?

Compounding this phenomenon, car manufacturers seem all too keen to jump into bed with these initiatives — Honda, Audi, General Motors and Hyundai, to name but a few, are already members of Google's Open Automotive Alliance (OAA).

There's a "me too" sense of urgency too; it's quicker and more scalable for Apple, Google and Microsoft to get their existing platforms into existing cars, than to create tailored solutions in a fragmented market.

Car manufacturers benefit too — not only do they save on HMI costs, they also benefit from the fast pace of technological advancement in the mobile and software space. Lengthy automotive design process cycles would otherwise hold back the integration of a contemporary HMI, as pointed out by Vera Schmidt, Senior Manager of Advanced UX Design at Mercedes.

> *"If you have (HMI) ideas now and you want to bring it to the vehicle soon, we try to accomplish it with this team by taking advantage of mobile devices and connecting them to the car to bridge that gap.*
>
> **Vera Schmidt, Senior Manager of Advanced UX Design at Mercedes**
> [source]

Being beholden to a hardware/software manufacturer – Plugging in the iPhone to make Apple 'CarPlay' work on the Mercedes Benz C-class as seen in the demo video previously or your Android phone with 'Auto'.

And speed is of the essence — these companies, software giants and automotive stalwarts alike, need to establish their presence in this field as quickly as possible if they're to get ahead of the trend.

In the short term at least, Model 3 may be the quickest and most viable way of getting a contemporary UI into a car by providing better usability and consistency across car types. It also plays into people's behaviour and the ways smartphones are already being used — for instance using Google Maps instead of traditional Sat-Nav via a cunning dash-mount hack

But there are obvious drawbacks to Model 3, which might hold it back:

A 2 dollar smartphone mount via niftycurly @ Intructables.com

1. Given the lengthy production cycles and that purchase cycles are less than one vehicle per two years, it will take many years for the model to become truly pervasive. According to estimates from GSMA and others, by 2018 there will be over 60 million connected cars on the road globally, driving some £30 billion ($51 billion) in annual revenue. That's just 6% of the cars on the road, which surpassed 1 billion in 2010 (according to a study by Ward's Auto).

1 BILLION CARS ON THE ROAD
6% (60 MILLION) CONNECTED
£30 BILLION ANNUAL REVENUE

2. Being beholden to a certain hardware/software provider, might be detrimental to user experience. For instance, demos of Apple's CarPlay system speak about the use of the iPhone in a car. It predetermines the use of a certain kind of device and an understanding of the idiosyncrasies of that operating system, which would make sense only for Apple users. What we actually need is synchronisation across multiple platforms to be more inclusive across world markets. (Car makers are looking into this issue — Press release from Audi). The best 'iPhone' experience might not translate well for everyone who does not use it.

3. Updates to mobile devices should happen at an equal pace to that of the in-car HMI (hardware and software). Update patterns in consumer mobile devices cannot carry over into cars, since that could present safety issues. Rules need to be communicated to independent app makers who wish to develop software for cars. Similarly, we need to consider the rapid change in mobile hardware in comparison to the car in itself. Cars are meant to last for years and mobile devices/software reach obsolescence far sooner. Would this mean a new paradigm in replaceable and modular HMI?

4. Access to deep telemetric data and control systems of the vehicle (eg seat positions, remote ignition control) in an app-based model could prove difficult with regards to driver and passenger safety and security. Regulations will need to change quickly to suit this reality. (See Hacking into the Tesla S).

We feel that these are just some of the challenges that need to be overcome in order for this model to be truly viable and attain any level of meaningfulness.

This leads us on to the radically connected car and custom module HMI car, outlined in Model 1 and 2 respectively, which use a bespoke, integrated HMI approach. This could be a better more meaningful long-term option, but like Model 3, also has some existing issues.

BLACK & BLUE

Tim Smith
Design Specialist

In the first and second model, car manufacturers' internal design teams create their own "tailored" HMI (though often the GUI and even physical buttons are repurposed from vehicle to vehicle).

The screen and, more recently, the multi-touch screen seem to be the default thought on HMI problem solving today.

In his article The State on In-Car UX, Geoff Teehan does not exude confidence in this approach. Contrary to Geoff Teehan's opinion, we believe the model itself does have some potential (discussed later), but currently is poorly executed.

The problem with current internally designed in-car HMIs is that they either look hard to use or they are hard to use (probably the same thing) — and let's not even get started on Pixel Perfect Precision.

They are often very moody and dark, with neon blue highlights and metallic textures. This creates another problem: they have an overtly masculine or sci-fi aesthetic which can alienate both women and men. The UI's approachability is thus often daunting, intimidating and unintuitive — the exact opposite feelings that they should evoke. And then there's the fact that they all end up looking the same.

HMI UIs have their fair share of practical, legal and safety constraints, of course, which can make a designer's job very difficult. However, it is fair to say that current HMIs have no aesthetic beauty, no identity of their own, no character. They are an emotionless, ugly, utilitarian, afterthought; a seemingly out of character approach for automotive companies that expend so much effort on exteriors and interiors.

> *"For those (automotive) manufacturers looking to go it alone, I don't expect much.*
>
> **Geoff Teehan**

The current in-car UI landscape

BRANDING: A MISSED OPPORTUNITY

Tim Smith
Design Specialist
ustwo

This “black and blue” aesthetic seems to be born out of a separate design stream to that of the rest of the car and indeed the larger brand.

As with almost all companies in the world, automotive companies have strict brand guidelines on which they base all of their communications, from logo treatment and typography to specific brand colour values. You can imagine that a Ferrari brochure would feature lots of red, as would a Ferrari website, a Ferrari app and so on. Why then, does the centre console of the HMI from the Ferrari California 2008 feature no red, but instead lots of blue (admittedly, the selected hardware is restrictive)?

We are not suggesting that HMI should necessarily follow brand books religiously, but we do feel that there is a wasted opportunity here. HMI should take inspiration from the entirety of the car, not just in the choice of colour, but in other aspects of both form and function – this is the point in which we interact with their product after all.

Ferrari California 2008 HMI

Photo credit:
Otis Blank for Petrolicious

There's real potential in blurring the lines between the exterior, interior and HMI design of a car, creating a coherent user and brand experience, from the colours to the look and feel, to interactions. With that in mind, neither the blue of the HMI in the example above, nor the square shape nor the cold, dry look and feel, fit in with the warm, sporty and exciting interior and exterior of the car.

The use of skeuomorphism in many car HMIs is primarily based on a need to solve the lack of affordance and feedback offered by the screens that have replaced buttons (as discussed earlier). However, this skeuomorphism seems to bleed into the entirety of the interface, which again pushes any branding into the back seat.

> *“They (automotive manufacturers) should see it (in-car UI) as a major opportunity to bring moments of joy and delight to customers. These are systems that allow us to physically interact with their brand.*
>
> **Geoff Teehan**

SKEUOMORPHISM: IT'S NOT ALL BAD

Tim Smith
Design Specialist
ustwo

Skeuomorphism applied to a UI

An aesthetic common in current automotive HMI UI's, and indeed with many UI's of the past decade, is skeuomorphism.

However, unlike contemporary UIs, the in-car HMI has failed to move with the times and shed the skeuomorphism — perhaps an artefact of the lengthy car production cycles we discussed earlier.

We've always thought skeuomorphism was too generic a term though, preferring instead to split this term into two types; *stylistic skeuomorphism* and *semantic skeuomorphism*.

To explain, let's take a random button from a UI. Using **stylistic skeuomorphism** you might give it a glass texture, perhaps some bevels around the edges, maybe even some light reflections and glare. While this may help it look more like a physical object, it's not necessary for the understanding of the function.

However by applying **semantic skeuomorphism** to that same button, you can imply that the button has depth, which helps communicate that it is pressable.

“ Affordance is an object’s ability to convey its function through sensory means, for example a button suggests that you press it by being slightly raised; This technique can also be used in digital design to lead users into interacting with objects.

Pixel Perfect Precision, ustwo

This simple shadow or edge adds an ‘affordance’ to the graphical user interface, which is pivotal in helping users find operational cues. (We cover this in more detail in our ustwo PPP document for best practices in GUI.)

Semantic skeuomorphism works with visual metaphors to communicate a meaning, much like many icon designs. For example, the attachment ‘paperclip’ icon in email clients: it’s not an aesthetic style, nor is it literally demonstrating the function. It is a metaphor that effectively communicates the function — which is now so well-known that is has been adopted as a standard.

Attachment ‘paperclip’ icon from email clients

Within today’s car dashboard, skeuomorphism also manifests itself in these two distinct ways. Just as skeuomorphic UI buttons look like analogue buttons of old, car HMIs are derived from a legacy of analogue or mechanical interpretations of pre-digital car dashboards.

The first, stylistic skeuomorphism, presents itself in the form of metallic sheens and bezelled graphics. This only acts to compound the masculine or sci-fi look we discussed earlier.

‹
Toyota GT 86 speedometer

You could argue that this aesthetic is informed by the materials used within the car's interior, or that in fact the faux leather and wood effects are a form of skeuomorphism themselves. Regardless, the styling, the blurring of the line between the design of the car itself and that of the UI is something we find interesting.

The second, semantic skeuomorphism, is apparent in the familiar speedometer.

The early speedometers worked directly from the engine: a cable connecting the two pulled the pin left or right depending on the exertion put upon the engine. Though these mechanics are no longer used, the same method to communicate velocity is still adopted in nearly all cars. Is a dial pointing at a number really the most effective way of communicating a driving speed?

There is an argument that it signifies a relative position — akin to 'How many minutes to 2 o'clock?' as seen with traditional watch-faces. But there are new and more relevant measures for speedometers now, such as 'How close you are to the speed limit?'

So, it is, in a way, a legacy; the familiar representation carried over from a time when that method was the best approach within technological and mechanical constraints.

The familiar is a powerful signifier of meaning. Just look at the paperclip example discussed earlier. However, learned behaviours and new signifiers are being adopted all the time, especially in this era of the rapidly evolving smart device, and especially if they're efficient, a pleasure to use and easily understandable. The transformation from the skeuomorphism of iOS6 to the flat, motion oriented design of iOS7 is an obvious example.

So, the current state of in-car HMIs suffers largely from the emergence of the screen and the multi-touch screen in the in-car environment, or more precisely, the poor appropriation of the technology. Car manufacturers' eagerness to use the screen as a solution to mapping and learnability problems has meant that new problems have emerged in the infancy of its adoption.

As this technology continues to advance and the experiences mature, we may start seeing some changing patterns in in-car HMI that finally make sense. ■

Photo credit:
Otis Blank for Petrolicious

LOOKING AHEAD:

DESIGNING FOR THE IN-CAR HMI

HARD & SOFT INTERACTIONS

Harsha Vardhan
Interaction Designer
ustwo

Before we discuss our thoughts on the best approach for in-car interactions, we will touch upon the types of interactions that exist in the in-car environment.

In-car interactions can be split into two distinct types: hard and soft.

Hard interactions can be defined as deliberate manipulative actions performed by the driver. Examples are: changing the drive position using a button, using an infotainment system via a GUI or inputting location data into the sat-nav.

Soft interactions can be defined as the actions performed by the machine as non-deliberate inputs provided by the user.

Self-cancelling turn signals are an example of a soft interaction — where the machine autocompletes a sequence of actions without any user input.

The latter type of interaction especially is coming to prominence with the advent of embedded interior sensors and the notion of the connected car.

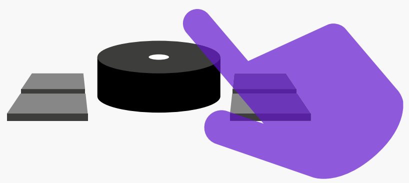
> *“A machine is beautiful when it’s legible, when its form describes how it works. It isn’t simply a matter of covering the technical components with an outer skin.*
>
> **Konstantin Grcic (2007) via elasticspace.com**

Some of the possibilities have been exploited with contextual information displayed in HUDs (Heads-Up Displays), auto dimming of interior lighting, and even experimental tracking of closed eyelids. As an aside, we feel soft interactions require the greatest amount of care and appropriateness in execution since there is a thin line between being assistive and in being a distraction.

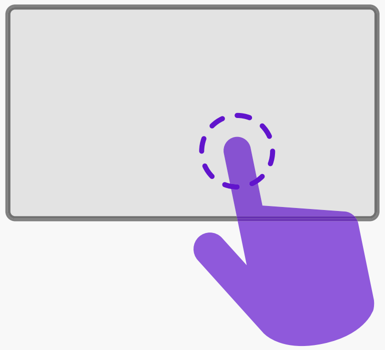
We believe that combination of meaningful hard and soft interactions is the key to getting the best out of HMI in a car.

In the sketch (right) we have laid out what could be the set of possible interaction paradigms. This outlines some of our own research into near-future interaction possibilities using current technology.

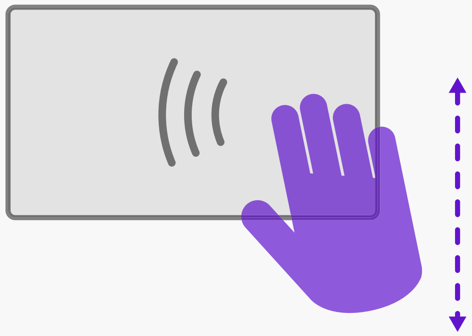
We will now delve into each of the above interaction paradigms.



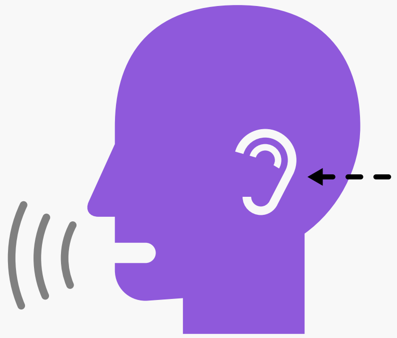
A. Haptic controls with embedded touch controls



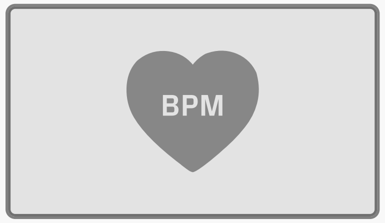
B. Touchscreens with possible Haptic feedback



C. Gesture control with visual & aural feedback loops



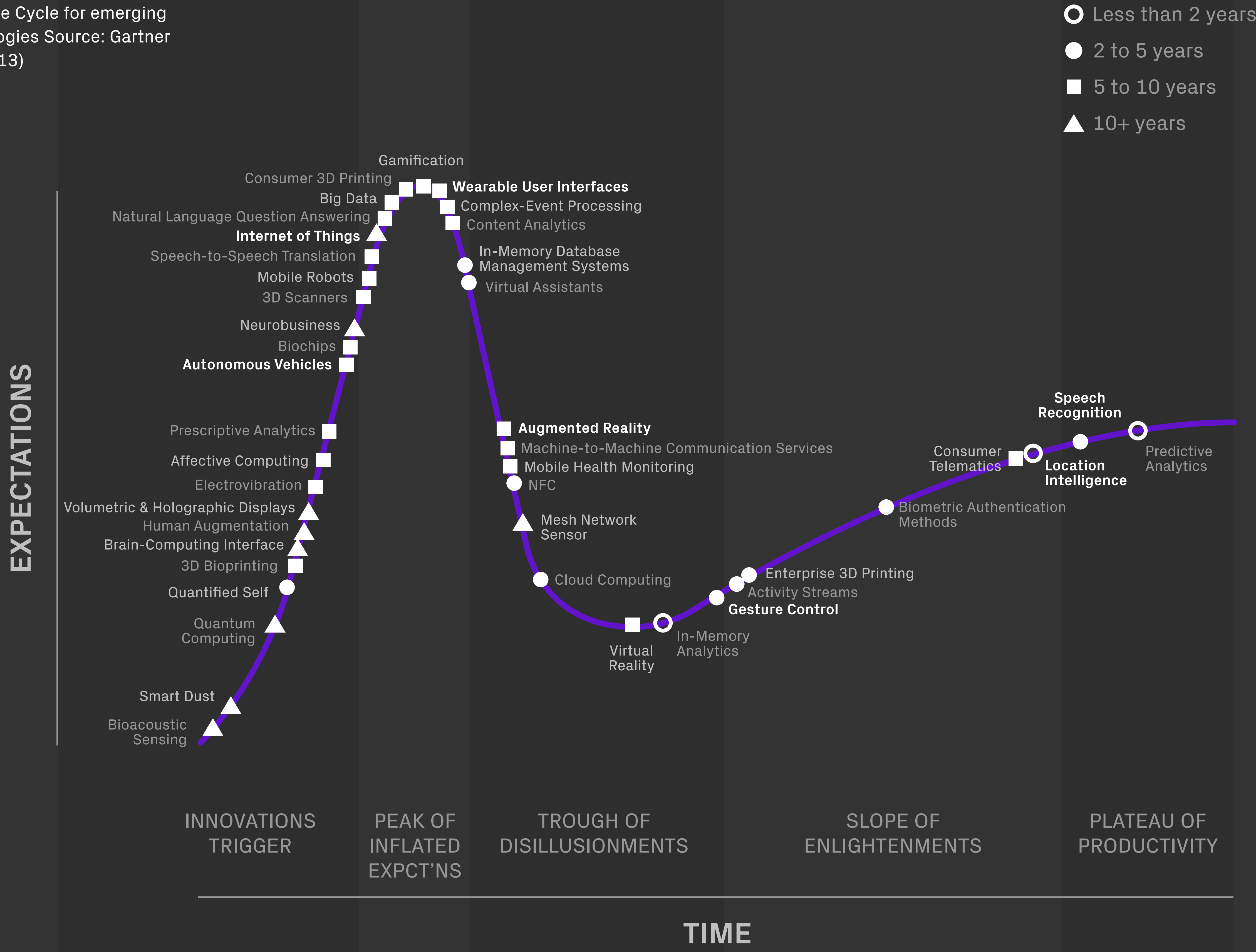
D. Voice control & feedback



E. Soft interactions aided by computer vision

F. Contextual information on secondary displays (e.g. HUD's)

The Hype Cycle for emerging technologies Source: Gartner (July 2013)



A. Haptic controllers with embedded touch surfaces: hybrid interfaces

Early BMW i-Drive Touch, late 2000's. Control knob next to the shifter and screen

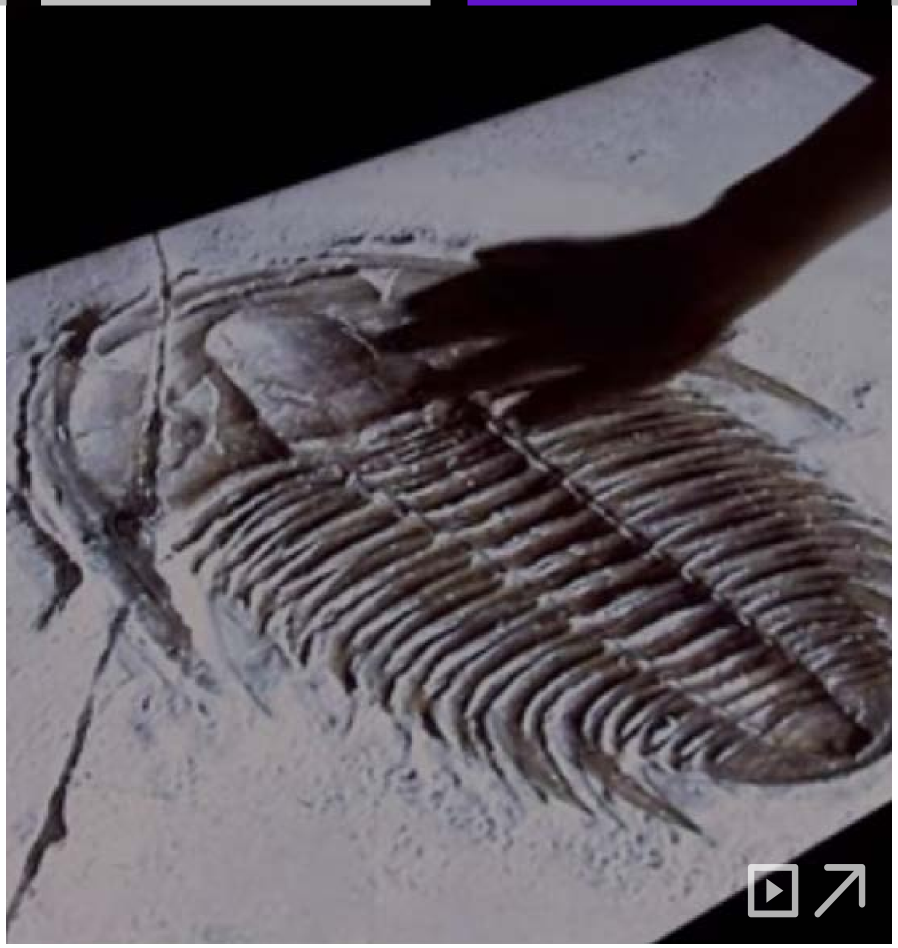
Let's take a closer look at the i-Drive controller that BMW employed in the late 2000's.

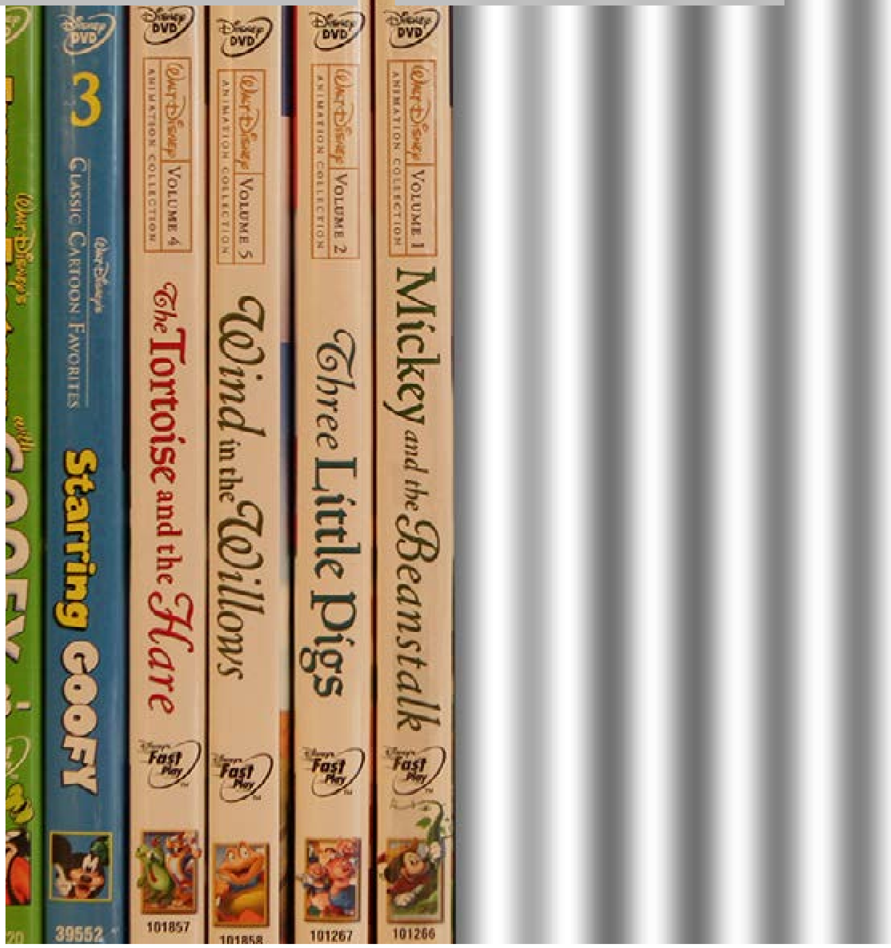
In this video, note the issues with modes — affordance and mapping a circular motion into a linear output on the screen.

BMW went on to introduce the improved i-Drive Touch in 2013 to alleviate some of these issues by introducing a touch interface on the control knob itself (as shown in the video).

Improved BMW i-Drive Touch in 2013

This form of hybrid interaction presents a significant improvement because it allows more active and tangible control of on-screen GUI.





B. Touch Screens with Haptic feedback

Touch screens are being put forward as the sole modes of control in automotive HMI, as demonstrated in the large-screen iterations in the Porsche 918 and the Tesla Model S.

Although they appear to offer a simple alternative, they are in fact problematic with respect to learnability, as discussed earlier. They can also be very distracting, because the driver has to rely on visual feedback all the time and cannot form a muscle memory or map of the controls over time.

An interesting set of experiments being carried out at Disney Research points to the way forward, where tactile rendering algorithms are used to simulate rich 3D geometric features (such as bumps, ridges, edges, protrusions and texture) on touchscreen surfaces.

If applied meaningfully, this could allow a muscle memory or 'feel' for controls to develop over time.

This technology can be seen on the Disney Research website.

^

Left: Porsche 918 HMI

Middle: Tactile Rendering of 3D Features on Touch Surfaces by Disney Reserach

Right: An array of 1D Gaussian bumps are rendered to create DVDs, books and other stack of things. Disney Research

A notion taking root in people's minds, thanks to these guys

C. Gesture control with visual and aural feedback loops

Using gestures to control certain aspects of HMIs is an exciting concept. This is primarily because it presents an opportunity to bring back the direct control and feedback which existed in early cars, although it is not without problems.

The sensing of 3D gestural data is getting progressively easier, not only because of low cost sensors and processors, but also as better algorithms become available.

3D gesture control as a concept is also taking root in people's minds, because of gadgets like the Leap Motion and Kinect controllers.

We can detect not just macro changes in physical characteristics, like nodding, facial position and hand gestures, but also micro changes like eye movements. However, the new interaction patterns emerging from low cost computer vision have not been fully cataloged and understood, which poses a challenge when mapping and learning a gestural interface.

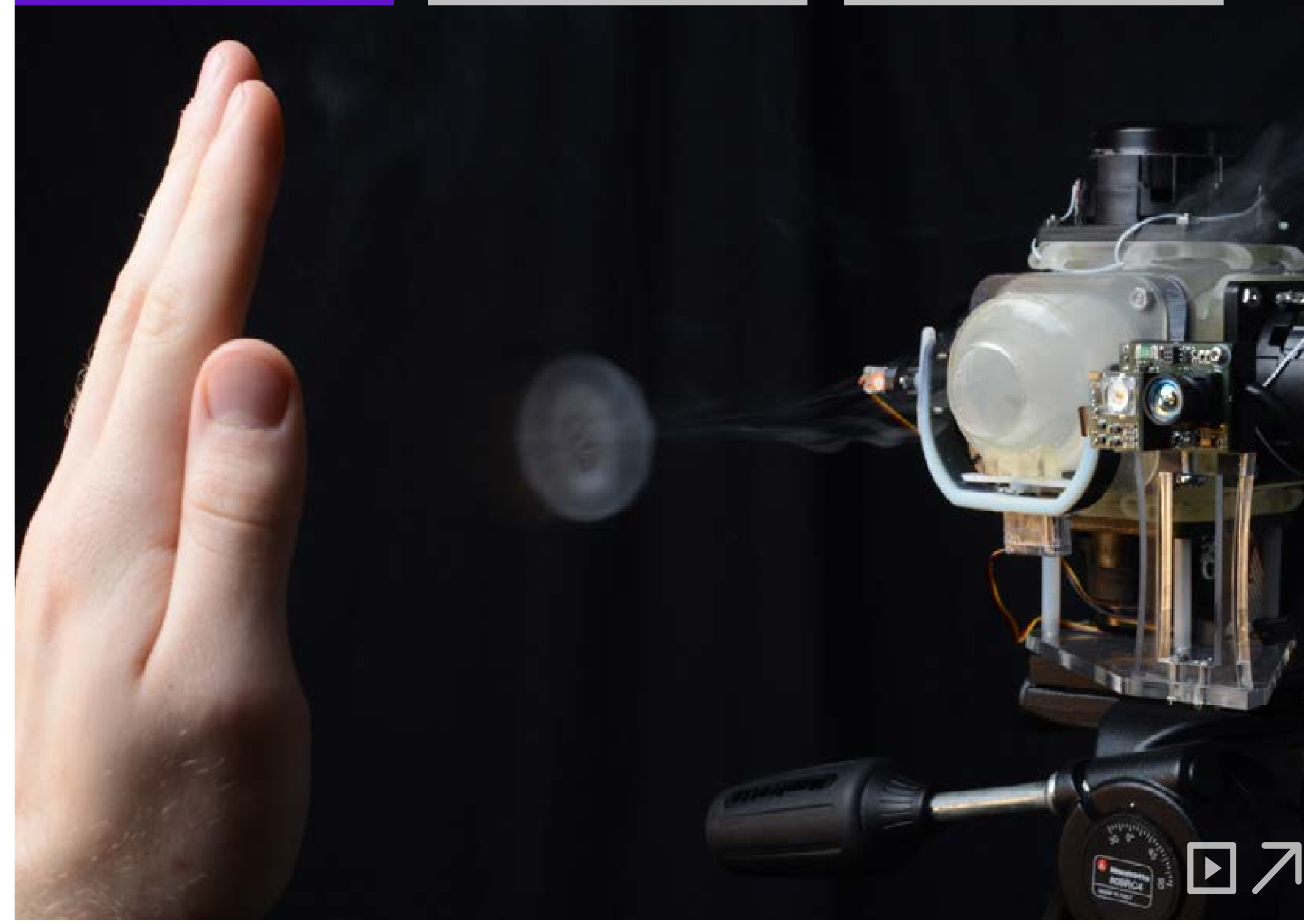
There are literally hundreds of 3D gestures possible and it takes time to learn and understand a set pattern and thus in its present state cannot be relied on as a pure interaction — especially with regards to safety.

This was indeed a key issue in our initial experiments using both the Leap Motion controller and the Kinect as primary modes of in-car control. We found, as with any new control, gestural interaction is not necessarily intuitive.

A concept using the Leap motion controller as shown below from Denso and Chaoticmoon

The rich feedback of physical interactions — clicking buttons, the movement of levers, gears falling into place — has not translated well into the fuzzy digital space. ‘Minority Report’ style interfaces remain a fallacy (The fallacy of a ‘Minority Report’ style interface).

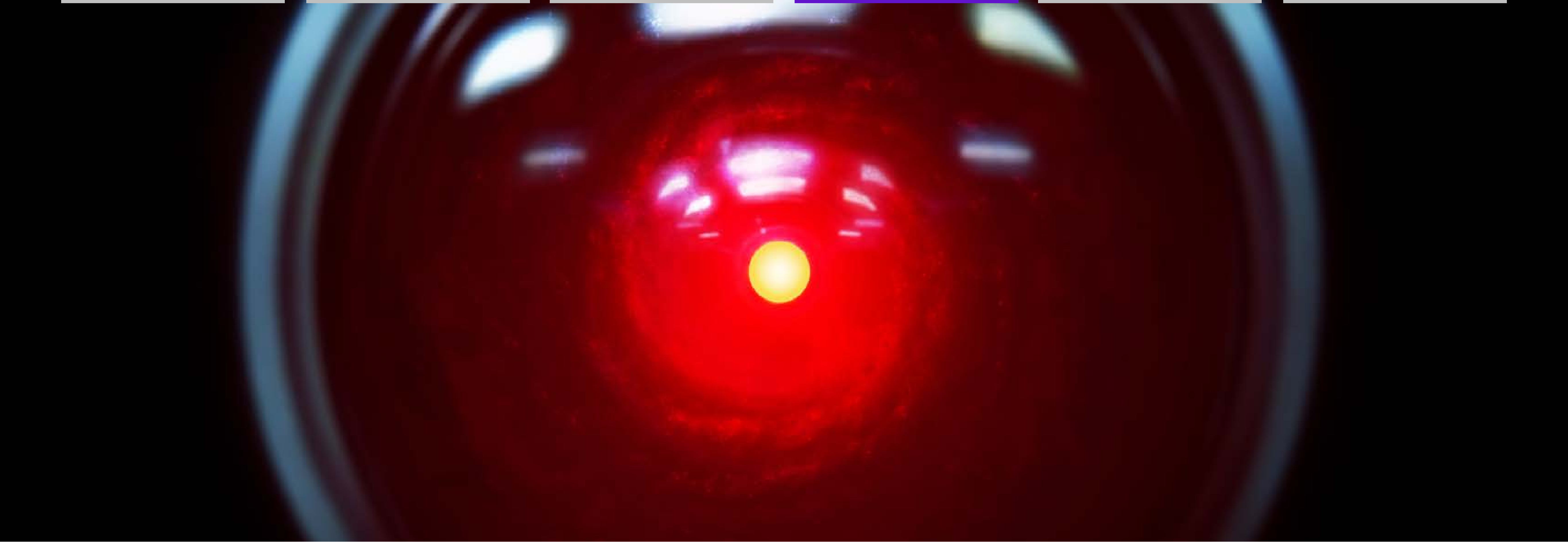
Also watch a concept using the Leap motion controller from Denso and Chaoticmoon. There are no buttons — only visual feedback is employed — which introduces the problem of fine grained control and learnability.



The AIREAL device by Disney Reserach emits a ring of air called a vortex towards a user’s hand. The vortex can impart a force on the user’s hand, enabling a range of dynamic free air sensations.

This issue with fine grained control has been the focus of research institutions over the last few years and we find this exploration by Disney research to be amongst the interesting ones — ‘Aireal: Interactive tactile experiences in free air’.

Here they prototype a new low cost, highly scalable haptic technology that delivers expressive tactile sensations in mid air as part of their long term vision for creating large-scale augmented environments which can deliver compelling interactive experiences everywhere and at anytime.



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HAL 9000 from 2001: A Space Odyssey

D. Voice control and feedback

Voice based interfaces have occupied imagination ever since the pop culture exposure to the eponymous HAL 9000 and more recently in the movie 'Her'. Though we are far from achieving human-like conversations with machines, due to continuous advances in natural language processing and recognition, the last few years have seen a number of high-fidelity consumer applications seeing the light of day (in essence this is a form of AI though some people might argue that it is not — a strong case of the 'AI effect').

Siri and Google Now in mobile OS's have also been playing a strong role with in-car interactivity with companies such as Nuance supplying their software expertise to manufacturers such as Ford — seen in their Sync range of HMI.

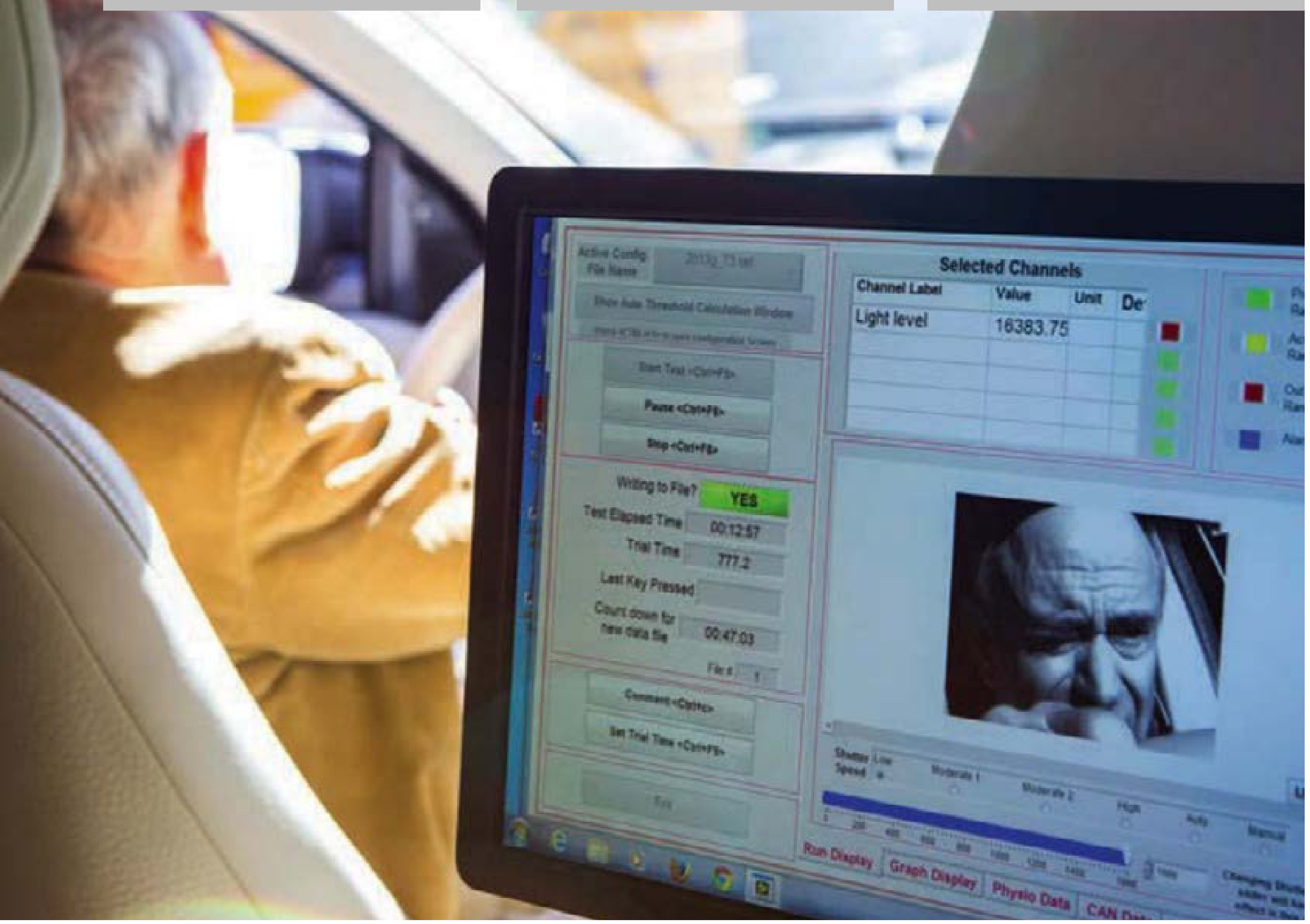
The promise of voice control lies with two factors, one in replacing physical and digital controls moving into the land of no UI, where one can freely converse with HMI and secondly minimising the distractions which come from the manual operation of HMI, targeting increased safety.

Voice input ‘Siri’ available in Apple CarPlay

Vocal interaction design is a new challenge. It is easy to say that voice could be a no-brainer in terms of next generation user interfaces, but we need to critically understand implications before designing for the same. In our research we find the following factors (among many) to be quite important to consider;

1. Discrete and continuous control: This is the difference between the on and off states of a button and the continuous rotation of a knob. Voice can play a large role in functioning as an effective discrete control e.g. ‘turn on radio’ or ‘radio’, but may not be as effective as a continuous control while changing volume, which operates over a range e.g. ‘Increase volume… make it higher… higher…’, as it operates as an abstract, analogue, inexact notion.

We then get into the fuzzy area of allowing a user to set presets so that a computer understands what he/she is trying to achieve or time based learning where the computer understands intention by gauging past interactions e.g. ‘higher’ can mean increase by 20%. This fuzziness could lead to increased confusion and frustration if not dealt with carefully. A study into voice interaction and distraction.



2. The problem with 'Strings' and 'lists':
There is a challenge in dealing with the input of strings of sentences (alphanumeric data entry e.g Sat-Nav) and cognitive load it poses on a driver.

Though one would think this is where voice input could be ideal, by eliminating the need to enter text via a keypad, studies point to the contrary. Research carried out at the MIT AGELAB and the New England Transportation Center, point out that the distraction and engagement levels of voice are comparable to that of manual operations and the subjects of the study rated these parts of voice interfaces to be as demanding as using knobs and buttons.

The complexities in the interface design arise from many multimodal demands posed by the technology. Among them are having to remember lists of information as spelt out by the interface. One of them is a behavior called the '*orienting response*' — which often took the form of subtle, seemingly unconscious shifts in posture as the driver spoke to the HMI. A case of personification of technology.

Left: Driver frustration in research carried out at the MIT AGELAB and the New England Transportation Center

Right: Voice input available in Android Auto

> *“The destination entry task was the most time consuming, requiring an average of 111 seconds to complete in the first two studies. Task completion time was not a matter of problematic speech recognition... it was a matter of interface design.*
>
> **Seeing Voices, MIT**

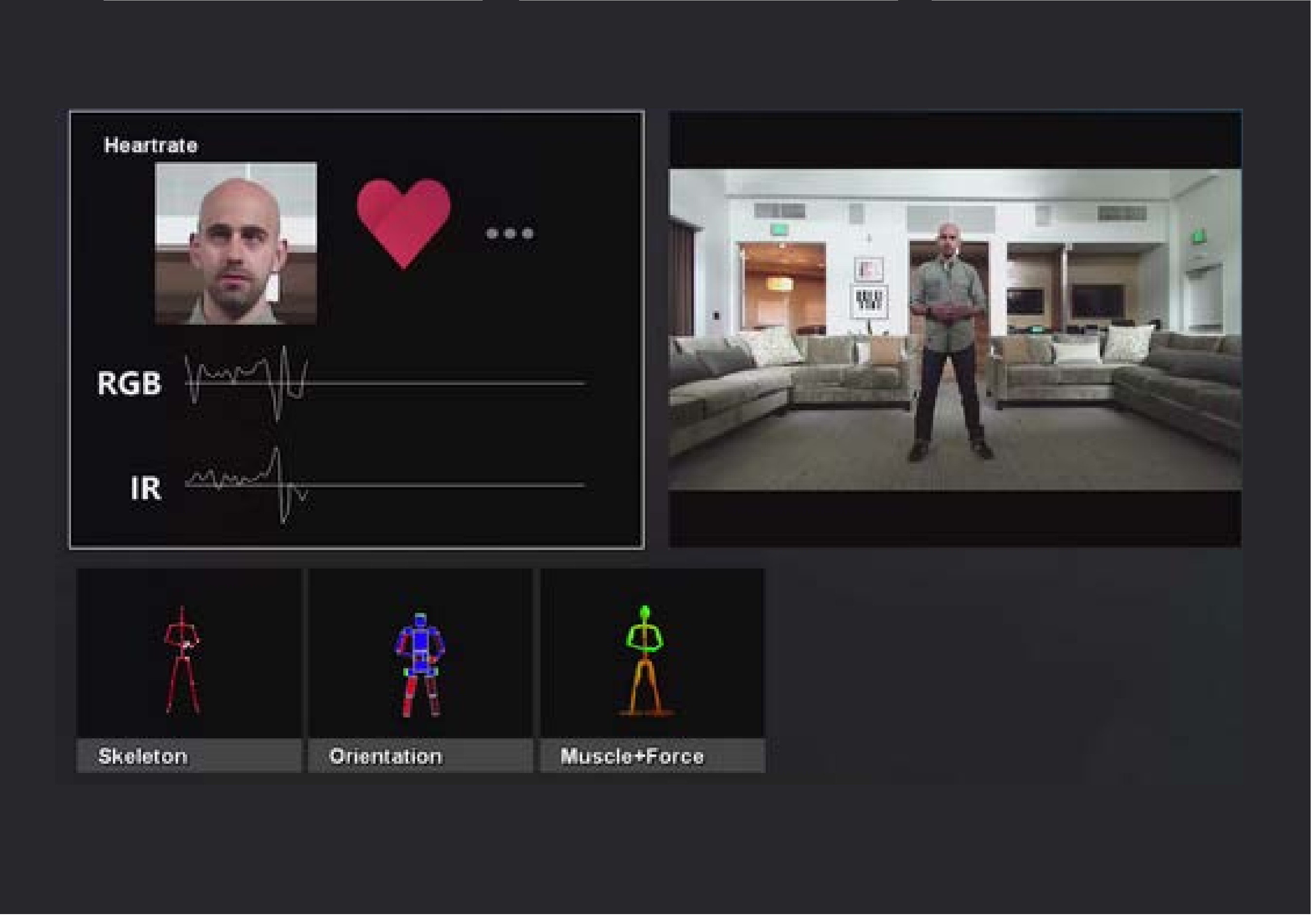
A way to effectively deal with the above issues as found by the study is by offering appropriate confirmations — both visual and aural. Treating a person as a whole rather than just focussing on targeting the ear and voice.

The orienting response often relies on visual feedback to the verbal input on the driver's part. For instance, Apple with it's CarPlay has tried to address the issue by deactivating the UI whenever possible. But the implications of these modes of automatic behavior on part of the interface have not been studied in detail as yet.

3. Recognising emotion in voice: This seems to be the next step in Natural Language processing — where mood and emotion are triggers for in-car reactions. Approaches being taken by Google and Nuance.

Voice input available in Ford Sync 2015 Ford Mustang

> *“ Designers must remain aware that, although they may be targetting the ear and the voice, what they are really dealing with is the entire person.*
>
> **Seeing Voices, MIT**



E. Soft interactions aided by Computer Vision

The ability of cameras to track micro-movements in pixel data allows sensors in the car's interior to detect a driver's physiological data. This can produce both synchronous (real-time) and asynchronous reactions (with a deliberate time delay).

By **synchronous reactions** we mean immediate and real-time reactions to changes in physiology, like the movement of a driver's eyelids or reactions to gaze detection.

Infrequent movement can signify a tired driver and thus a car might prompt the driver to take a break or offer the driver directions to the nearest motorway services.

Asynchronous reactions are time-based. For example, tracking a driver's heart rate over a journey and presenting them with hot spots where there are data spikes. Much like how a car's fuel consumption over a journey could be mapped and studied, we can study and learn from physiological data.

The Kinect One and 'Eulerian video magnification' have both been used to non-invasively measure heart rate (BPM) in a research setting. Happily there is already an element of consumer trust when it comes to such personal metrics — a survey carried out by Cisco Systems revealed that 60% of car owners would be willing to share biometrics such as fingerprints and even DNA samples if it would improve car security.

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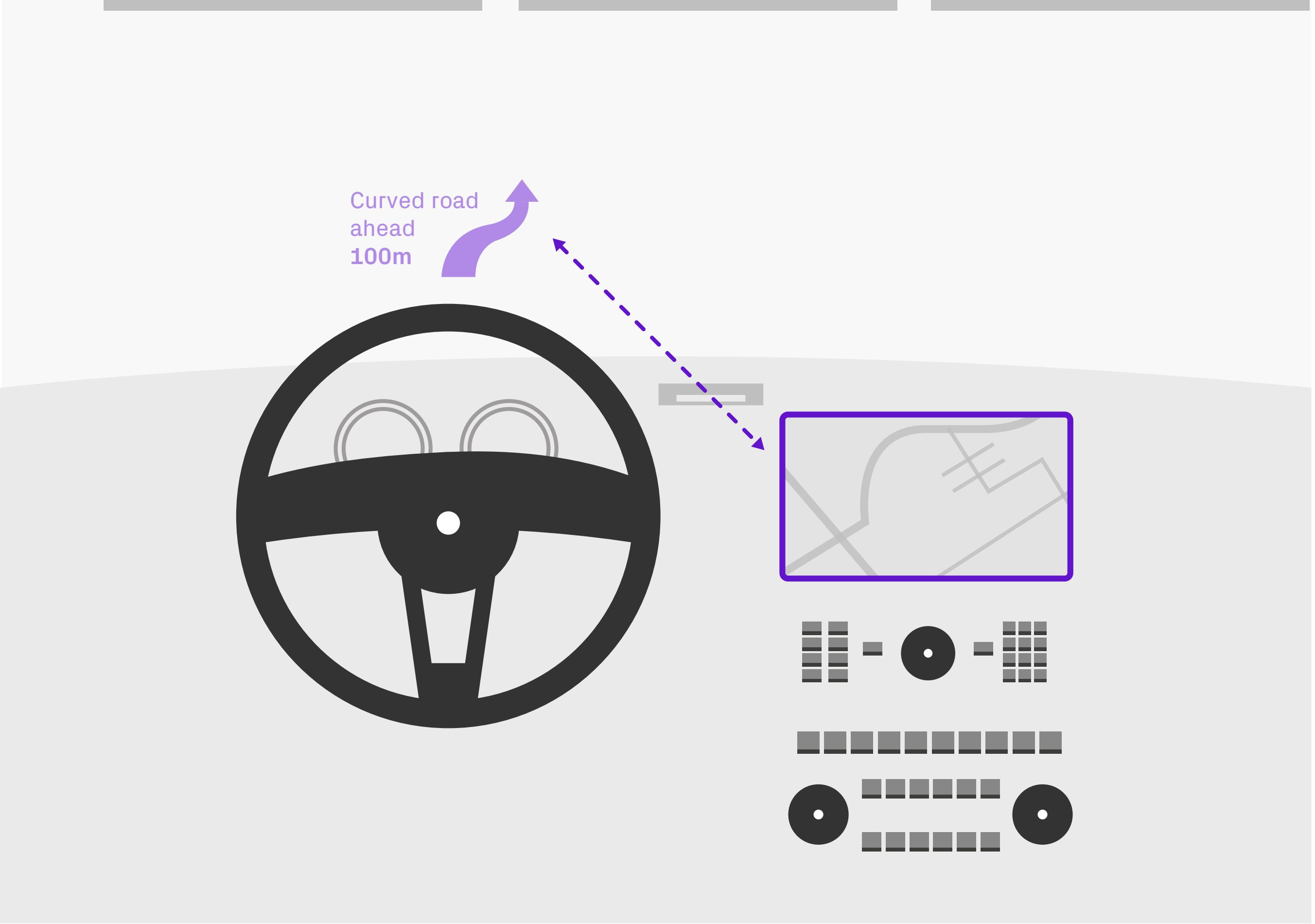
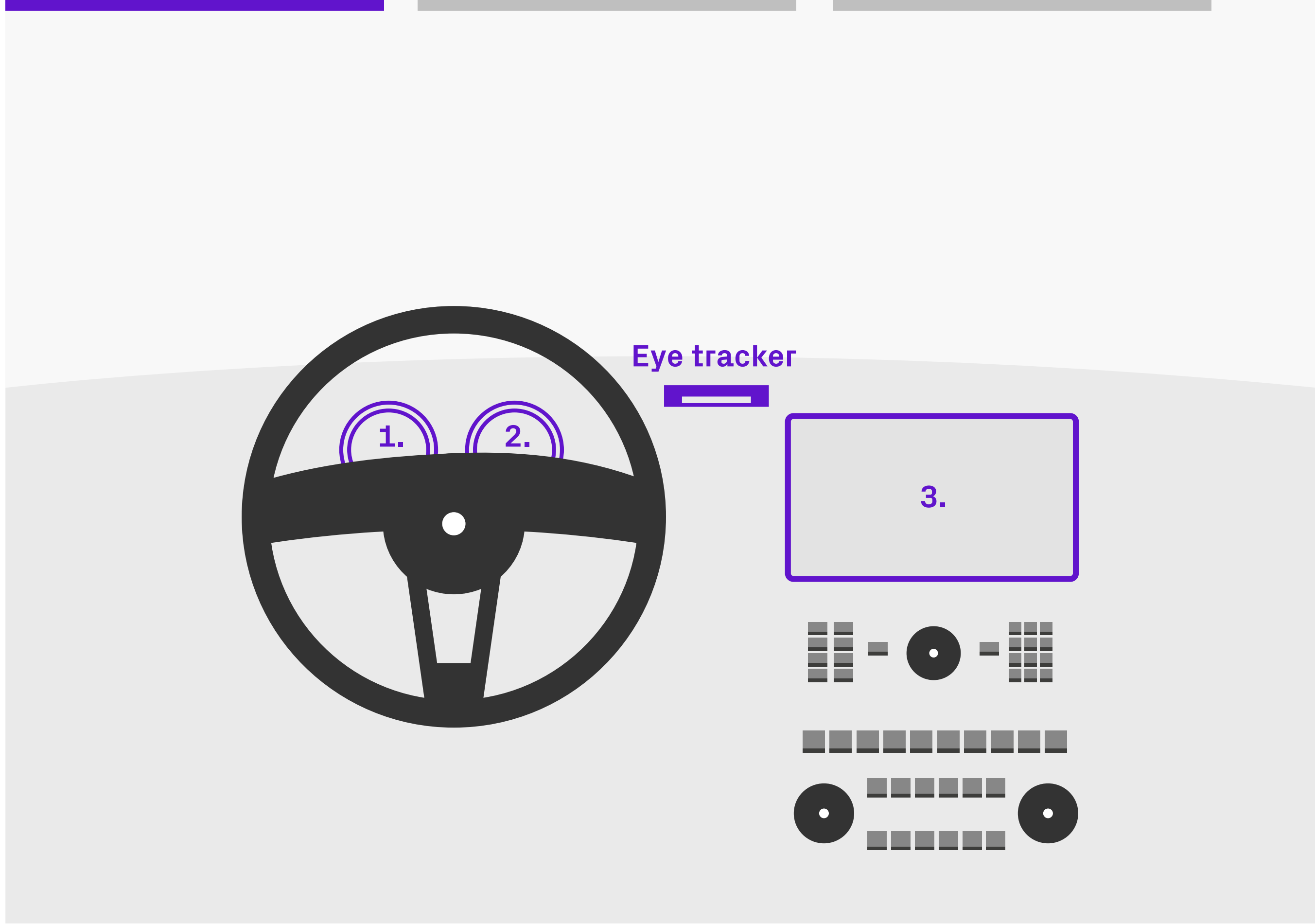
Left: Capabilities in the new Kinect to detect micro-fluctuations in physiological data

Right: Enabling cameras to measure BPM - Eulerian Video magnification - MIT , Quanta research center Cambridge





F. Contextual information on secondary displays (e.g. HUD’s)

We could break the visual emphasis towards a central console and provide displays for the driver based on when data is required (temporal, left) and where it is required (spatial, right).

For instance, information can be broken down into a number of displays, to provide turn-by-turn navigation data when a driver requires it, perhaps using HUDs.

Temporal reactions.
Turn-by-turn navigation on a HUD only when GPS is activated

This information can also be displayed where the driver is looking, via gaze detection techniques.

What technological implementations have we seen so far?

The first main implementation is the use of secondary displays in cars, like HUDs, for providing information on or near the driver’s line of sight have been in use since the late 1980s.

Spatial reactions.
An embedded eye tracker on the dashboard activates screens the driver is looking at only, minimising distraction

The Land Rover Discovery invisible bonnet concept is a more recent idea, where a combination of contextual on-road information and actual off-road imagery from grille cameras is viewed through a HUD. Digital immersion through the use of cameras is something we expect to see more and more in in-car HMI, used mainly by augmented reality.

Land Rover Discover: Invisible bonnet concept

In a similar vein, the BMW 'Vision Future Luxury' speaks about the 'contact-analogue' HUD for the driver which augments the real-world view by projecting information directly within the line of sight. Buildings, traffic signs and hazards can be highlighted directly in the real-world environment, selectively directing the driver's attention to specific information.

BMW Vision Future Luxury

Eye tracking technology software

Caterpillar and Seeing machines collaboration

Then we have gaze detection or eye-tracking displays, where specific portions of the GUI become active depending on where the driver or passenger is looking (spatial reactions). This has the potential for minimising distractions and, coupled with the temporal reactions, can be quite powerful.

It's early days yet, but quite a few companies are working to integrate trackers into driver assistance systems, tackling issues like driver fatigue, especially for large commercial vehicles.

For instance a Caterpillar and Seeing Machines collaboration. These systems are built using a combination of software (face and gaze tracking algorithms) and hardware (cameras and processing units to integrate with on-board assistive systems).

In a similar vein, Tobii has eye tracking systems which they have experimented with in cars and games.

> *“The integration of eye tracking into the game experience is literally a game changer – not only for the gamers themselves but developers.*
>
> **Bruce Hawver, CEO of SteelSeries**

^
Tobii eye tracking enabled game

CONTEXTUAL EMPATHY

Tim Smith
Design Specialist
ustwo

We're still at the dawn of the in-car UI space and it's worth remembering that there's more to how you interact with your car than a UI on a screen, as demonstrated previously.

While we do see a future for the screen, and by appropriation, smart devices in in-car experiences for example, a more tailored approach has far greater potential, both in conjunction with and free from any platform bias.

The in-car space needs to mature into something that is as sophistically defined and crafted as that of the smartphone. As with smartphone and app design, context and the user need to be at the forefront of in-car HMI design, but they are so often overlooked. A person driving a vehicle is in a very different situation than a person sitting on their couch at home. This is where the term 'contextual empathy' comes from; understanding and designing for a specific situation.

Take maps, for example. Maps and navigation are clearly of use in the automotive space, but that doesn't mean simply putting a ubiquitous service like Google Maps onto a screen.

> *"Before you become too entranced with gorgeous gadgets and mesmerizing video displays, let me remind you that information is not knowledge, knowledge is not wisdom, and wisdom is not foresight. Each grows out of the other, and we need them all.*
>
> **Arthur C. Clarke**

TomTom sat-nav

> *Carmakers can do better - and the more voices we have telling them how to do so, the safer our dashboards will become.*
>
> **John Pavlus, Fast Company**

A driver has far less time to digest a map than a pedestrian, so the selection of which information to display when must be carefully considered. There's perhaps less of a need to show roads that are not part of the route to the destination. Tom Toms and other such devices have already adopted the same contextual thinking — they are bespoke, tailored devices for the specific context. You certainly can't send emails or Facetime anyone from them.

Safety is of course a major consideration which makes designing for the in-car HMI unique to other UIs.

Many recent articles have raised safety concerns about screens in cars, namely the potential distraction to the driver (eg Matthaeus Krenn's excellent A New Car UI Concept). Safety is paramount, but these articles focus on one scenario; that of the driver while they are driving.

There's more to the in-car experience than the driver and more to it than the driving — the automobile and the drive are a romantic and aspirational experience after all. That's where the importance of understanding context comes back into play.

Encouragingly, during their presentation at the Build Conference at CES 2014, Microsoft acknowledged a difference in what one should expect from driver engagement during a drive versus the stationary context. Though only a prototype, Microsoft seemed to have done some solid field testing with their in-car concept.

An in-car experience will primarily involve the driver, but they won't always be driving. There's the getting into and out of the car, the waiting in traffic and a plethora of other situations.

How about the person in the passenger seat, the kids in the back and even the family dog in the boot? What about the car that communicates with the city and responds to the environment? A quality, safe, enjoyable and beautiful car HMI will cater for all of these stories and more.

This is a consideration Renault played to in their unveiling of their Initiale Paris model at the Frankfurt Auto Show in 2013. Renault's HMI housed a rear-seat touchscreen enabling passengers to be part of the navigation, or "journey exploration" process. LandRover's recent Discovery Vision concept also briefly alludes to empathetic user design, offering variations on the experience for the passengers.

Even with intentions of safety, there will be times when a visual platform, i.e. a screen or HUD, is the best way to communicate.

There are a number of technological and practical ways to facilitate this requirement, everything from the obvious — multiple screens for each passenger, to more abstract ideas such as stereoscopic screens where driver and passenger see different, but relevant information, and gaze detection whereby the system detects who is looking at the screen, with the driver taking priority. These are just a few ideas of many.

So, already we can see that the in-car context demands fresh thinking and design, from both a UX and UI perspective. And this is where so many issues arise in the current approach; a re-appropriation of the (touch) screen into a new context, the "empathy" lost in translation. The UI can help solve these practical and functional issues, but it also goes a long way to resolve some of the emotive problems associated with in-car HMI.

DESIGN CAN BE FUNCTIONAL AND BEAUTIFUL

Tim Smith
Design Specialist
ustwo

Honda 'Inner Beauty'
Civic Tourer

A great car has function and it has beauty, and should excel in both.

Beauty is a commodity in car design, a commodity that is sold so evidently in contemporary marketing campaigns, typically based on the vehicle's beauty and the lifestyle it can offer. Indeed, the beauty of a car is often favoured over its functionality.

We feel that all design should be as beautiful as it is functional — there is inherent beauty in the purity of function.

"It is not enough that we build products that function, that are understandable and usable, we also need to build products that bring joy and excitement, pleasure and fun, and, yes, beauty to people's lives.

Don Norman

>
Braun TP1 portable record player and transistor radio by Dieter Rams, 1959

Dieter Ram's work for Braun is a great example.

Why not bring the beauty of the car into the HMI, blurring the lines between the car's exterior and interior design with that of the UI to create one unified piece of design? A UI can be a part of the form of the entire car, not just a simple module or an island of interactivity in the interior.

There are some challenges with this approach. The lifetime of a car production from concept to market tends to be five years or more, so logistically it might be difficult to keep the design thread that runs through different departments intact. This goes someway to explain the sudden emergence of smart devices in cars as we discussed earlier.

However, we believe that if the exterior styling, interior styling, trim and UI design teams work together from the very outset, this unified aspiration is achievable.

> *“Good design is aesthetic design — The aesthetic quality of a product is integral to its usefulness because products we use every day affect our well-being. But only well-executed objects can be beautiful.*

Dieter Rams — Commandments for good design

In fact, it’s encouraging to learn that Mercedes’ research and development department already utilise teams of designers and researchers with backgrounds in art, design, user experience, engineering, psychology and software to conceive new features and designs under a unified approach [source].

The connected car model assumes a software focussed approach, but there may be further physical and hardware characteristics beneficial to a meaningful HMI. While creating a bespoke HMI for a specific vehicle or a range of vehicles has its challenges, it does ensure that the design does not date during the production lifespan of the car. As design changes are made by other teams during the project, you can react and adapt — this applies to functional, physical and visual design.

We see three main ways in which this process can be facilitated:

1. Design in regular system updates. This can help support the software of the UI, but should not be relied upon. Even if the car had regular and reliable access to the internet so that the OS / UI had systematic updates (a benefit of the mobile device connected car model), you can’t rely on the user taking action on, or even understanding, this process. Furthermore, a sudden change to the software, visually or otherwise, could cause serious safety concerns.

2. Design the HMI and UI in a templated, modular fashion from the start, so that the design can be re-appropriated as the project progresses. This could also help in re-purposing or rebranding the experience for other models, as is already the case for many of the physical controls and is how the car stereo system has worked for years.

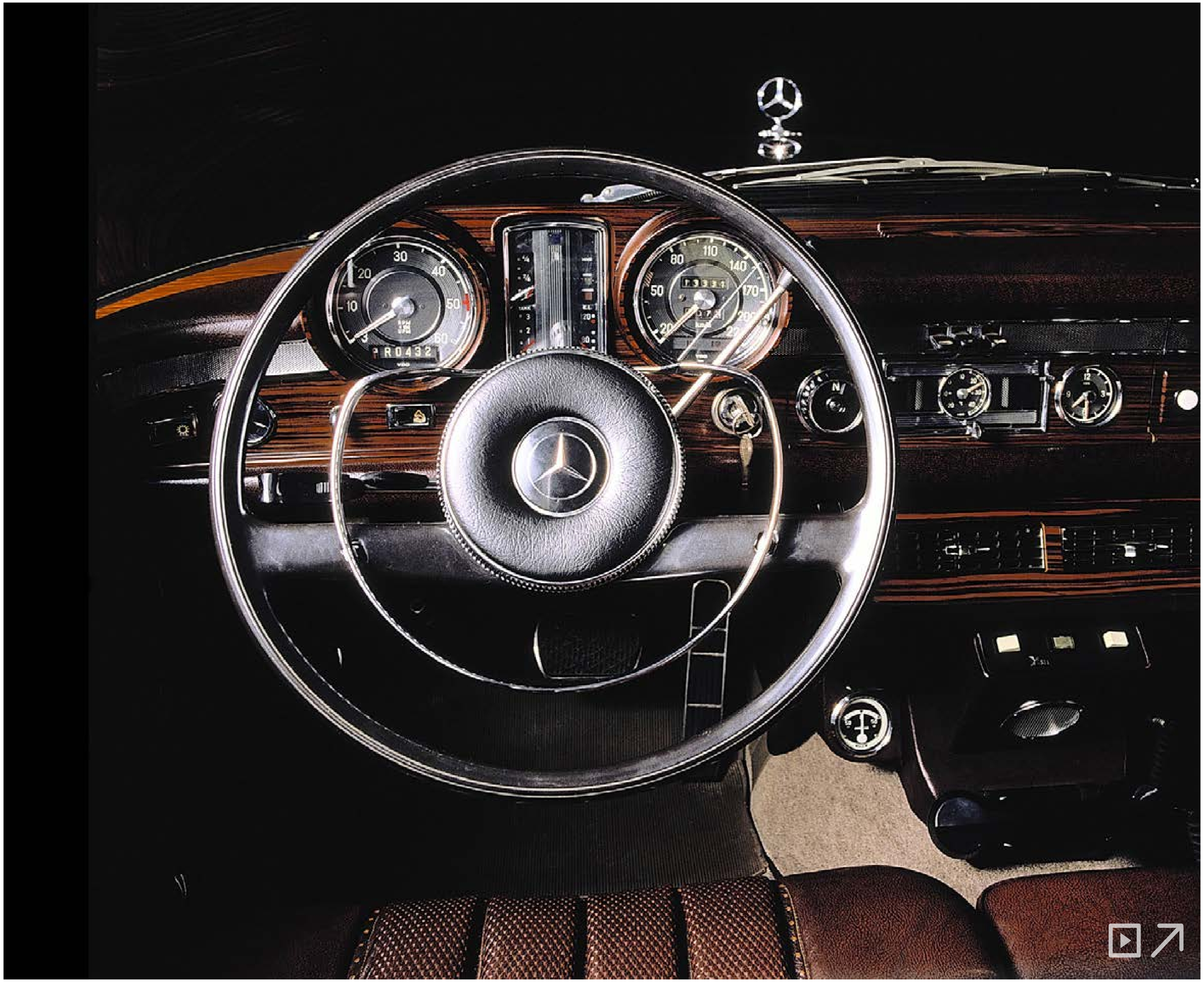
3. Do not design for trends but instead design for function and context so that the aesthetic does not age badly, or indeed at all. It is impossible to predict trends five years in advance, nor should you try. Besides, the driver has to live with the HMI and UI for the lifetime of the car far beyond the launch of the vehicle.

Photo credit:
Pictures Of Car Dashboards

Design tends to age badly if it succumbs to a trend. Conversely, there is something enjoyable in associating a car with its era, arguably an inherent part of the automotive experience and heritage. The HMI should be a part of that, as long as it is at one with the entirety of the car's design.

Best practise should be a holistic focus in influencing the design, which could include accessibility standards and automotive-specific standards, to branding to the context of the environment to traditional design best practices such as layout and hierarchy. Putting some real thinking and commitment into the beauty of the in-car UI is in itself a step forward and something we are particularly excited by.

So what does it take to achieve a functional and beautiful in-car HMI / UI and how does that differ from any other? This is something we have explored in our studio, both in internal projects and working with one of the world's leading automotive manufacturers. ■



1960 Plymouth GTX
convertible

OUR EXPERIENCE:
A NEW APPROACH

OUR APPROACH

Barnaby Malet
Lead Developer
ustwo

David Mingay
Creative Director
ustwo

At ustwo we see a significant opportunity for designers and developers alike to narrow the gap between the concept and engineering aspects of new product development, by using a lean and prototypical approach that traverses multiple disciplines from conception to pre-production.

We employed just such an approach when we helped a leading automotive manufacturer conceptualise the future of the in-car HMI experience.

Process at ustwo

Our approach in a nutshell:

1. Arrival at a design statement which forms a basis of exploration, with assumptions and hypotheses, — working hand-in-hand with product owners over multiple workshops.

2. Identification of significant technological and experiential drivers, to form a basis for a set of narratives. Narratives help us ask questions to test the weight of the design statement, while considering users and their actions in a particular scenario.

We created a scale model of our client's car interior to test the hardware and with users

3. Iterative investigation of each of the narratives with prototypes. This is carried out by focussing on testing with real users. The mindset employed during these investigations is to humanise interactions by rapidly building and testing variations.

4. Prototypes generally consisting of an interplay between screen-based user interfaces and spatial / product interactions, with each experience and discipline bleeding into the other.

5. We generally consider currently available consumer hardware as proxies for nascent technology. This enables us to probe the constraints of the tech, without waiting for the release of specialised products. APIs and SDKs available for certain hardware enable us to quickly prototype eg Myo, Kinect and Leap Motion.

6. Creation of an 'experience demo' which ties the narratives together into a working concept. The demo is a tool both for communication and as a basis for getting to know limitations and potentials for future production.

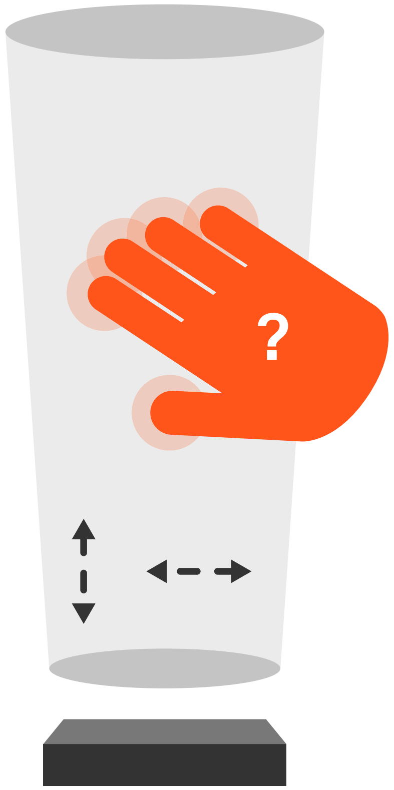
7. We also test visual design theories and ideas simultaneously with prototypes and demos, gathering user feedback as we test iteratively to form a guideline of best-practices for the visual / UI design (which incidentally has informed some of the thinking in this document).

Next, we speak about some of our specific learnings with the experiments carried out in the course of the project.

GESTURAL INTERACTIONS

Harsha Vardhan
Interaction Designer

Leap motion controller
& 'Column of Interactivity'



A key area of focus in our concept was the building of learnable gestural interfaces through micro-interactions and their triggers, rules and feedback.

One reason for this focus was that it can prove less distracting to perform as it avoids potential cognitive overload created by looking at and comprehending a UI while allowing the driver to keep their eyes on the road.

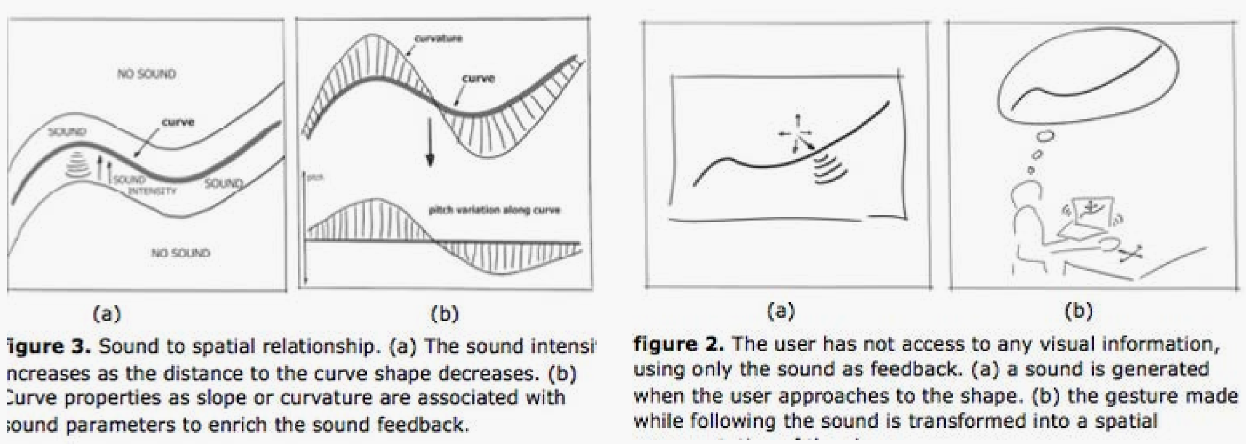
In doing this, we aimed to make use of the benefits of the technology and solve the associated problems for the in-car context.

In order to think about gestures clearly and identify what is meaningful, we used the system presented by Dan Saffer in his book 'Micro-interactions'.

In-car interactions in the context of driving need to be modular with very effective trigger mechanisms in the light of safety, with rules and feedback on the activation of those triggers. For example, the rule inherent to steering (a trigger) is that the car turns, with feedback given both visually and haptically when the act of turning the steering wheel becomes harder.

Through several rounds of testing with the Leap Motion sensor, quickly iterating with varying 'columns of interactivity and feedback', we found that understanding these issues was important for our users.

Tests were conducted by placing the Leap Motion in an ergonomically convenient and logical position for the driver from where they could interact with the HMI via gestures, unhindered by other physical controls (i.e. gear shift/stick).



From these tests our key learnings were that a meaningful gestural HMI needs:

A. A gestural interface with a focus on shortening the learning curve by using rich visual and aural feedback loops (car interiors provide for a controlled, fertile environment to affect rich feedback systems).

^
Recognizing Shapes and Gestures using sound as feedback – Javier Sanchez, CCRMA — Stanford University

B. Balance between meaningful gestures and on-screen GUI.
A couple of interesting research explorations point to the way this could be achieved, as shown above.

^
AHNE — Audio-Haptic Navigation Environment demonstration video by SOPI research group, 2011

DATA VISUALISATION & SEMANTIC SKEUOMORPHISM

Tim Smith
Design Specialist
ustwo

Shadows offer 'Affordability' to suggest buttons are pressable

While solving some problems, our concept also presented a visual design challenge, that being how gestural interaction and tangible interaction are distinguished visually.

Given that our concept had a mixture of buttons and non-interactive graphics, as well as other user inputs such as gesture, we applied semantic skeuomorphism (discussed in Part 3) in the form of a crisp shadow to pressable buttons only. This established a visual language that effectively defined all buttons as pressable and everything else not pressable.

Other signifiers were used to prompt the use of a gesture or voice, such as the the ergonomics and placement of certain sensors (as described earlier in "Mapping") and audio cues.

In another area, we shied away from skeuomorphism: the overly familiar speedometer. We discussed earlier how the speedo comes from the legacy left by mechanical and technical constraints, which in turn became a form of semantic skeuomorphism when those constraints were lifted by technological advancements.

The driver is within the speed limit, represented by the number, green hue and contained circle

However, is a pin pointing to a number the most effective way of communicating a driver's speed? We explored alternatives to stress test this established data visualisation.

In our concept, we redesigned the speedo with an expanding and shrinking ring that changed colour depending on how close you were to the speed limit (defined by the particular road limits using geo location). A simple number in a constant position within this ring represented the speed and the consistent position meant the driver could quickly glance at the correct spot on their dashboard, decreasing dwell time.

The driver is over the speed limit, represented by the number, red hue and over expanded circle

"MICRO-DWELL": INFORMATION IN PIXELS

Tim Smith
Design Specialist
ustwo

Nissan Versa Car billboard
Photo credit: Jason in Hollywood

When it comes to visual communication in an in-car environment, you want to achieve the opposite of what we're used to as designers.

That's to say the audience (in our case the driver and passengers) should be looking at your beautiful, painstakingly crafted design as little as possible, ensuring the driver is not distracted and has their eyes firmly focussed on the road.

This is where the term "micro-dwell communication" came from. We have touched on audio and haptic feedback, but there will be times where visual communication is necessary, at least within today's confines. In these instances, we must ensure that the driver is looking at the visuals for as little time as possible. It's not dissimilar to a billboard advertisement in which the message should come across instantly, though unlike the poster, the viewer should not dwell further. There are a number of design decisions that can be made to reduce dwell to a minimum, a handful of which include:

Photo credit:
Otis Blank for Petrolicious

Readability and legibility:
As discussed later, text should be kept to a minimum and should be as readable as possible. Graphics, as well as type, should be legible: contrast and scale play a part in this.

Grouping:
Information related to a specific context or scenario could be grouped. For example, music controls grouped on one screen, geo-navigation on another.

Hierarchy and quantity:
Ensure information is delivered with the correct prioritisation. Display as little information at any given time as possible. As a rule of thumb, we tried to keep information down to just three pieces per screen/instance.

Interactions:
As our concept utilised touch screen inputs along with gestural and vocal input, it was important to distinguish between and communicate them differently. Interactions should be done quickly.

›
Photo credit:
Otis Blank for Petrolicious

To accommodate these considerations, we found that by using graphic systems such as infographics, icons, “affordance” and colour-coding, we effectively reduced the length of time the user had to look at the visuals to understand what was being communicated.

In fact, understanding of the information and the way in which the system worked became quicker as the driver had more exposure to it. We even took this approach in redesigning the speedometer, as discussed previously.

TEXT & READABILITY

Tim Smith
Design Specialist
ustwo

We also looked at the very basics of design and sought to employ them in the most appropriate way for the in-car context.

The use of text in in-car HMI is a key consideration: it should be kept to a minimum. This will ensure readability (not to be confused with legibility). Paragraphs should be avoided completely, at least when the driver is actually driving. Long pieces of text are not only uncomfortable to read but also distracting — the length of time to consume the information is too long, which can be dangerous.

Overlaid text and graphics should always have the appropriate light contrast (true of all UIs, automotive or otherwise). This will ensure legibility.

Despite some experimenting, a dark background seems to be the shade of choice in automotive design. There's a reason why so many car UIs have dark backgrounds, and that's because they are less distracting and reduce glare. But more on that later.

Given that the background should be dark, the best option for text is white or preferably very pale grey or pale colours. We actually opted for a dark grey background as deep black was too severe against paler pixels and very high contrast text can be difficult for people with dyslexia to read.

In some digital design instances the inverse of black on white is frowned upon (with some AA accessibility exceptions), but the requirement of a dark background and the short engagement nature of the interaction negates this concern. This is thanks to the "read versus scan" hypothesis.

> *"Good screen design happens in the subatomic level of microtypography (the exact definition of a typeface), the invisible grid of macrotypography (how the typeface is used), and the invisible world of interaction design and information architecture.*
>
> **Oliver Reichenstein**

a b c
d e f g
h i j

Reading involves focusing on words and characters for a thorough comprehension of the subject. This requires a lengthy dwell time.

Scanning involves skimming the information for a broader comprehension of the subject. This requires relatively short dwell times and often a “glanceable” understanding of the information is achieved.

Reading paragraphs of white text is stressful on the eyes due to all three types of colour sensitive visual receptors being stimulated simultaneously which “overloads” the eye. The projected light from the white (or brighter than dark pixels) of close proximity graphics, such as alpha-numeric characters, scatters into neighbouring characters, which is obviously detrimental to readability.

However, putting stress on the user’s eyes is not so much of a concern when scanning the information because long visual fixations should not occur (if the information is appropriately designed). Given that we should expect what we call “micro-dwell” times from the driver, reading is an unrealistic expectation anyway. Scanning, on the other hand, is a more appropriate expectation for which we can and did design for — at least during the driving experience. White (or pale grey) on black (or dark grey) therefore not only supports the anti glare colour scheme, but also makes it easier for the driver to scan the information quickly, the micro-dwell time negating eye strain concerns.

This white on black design also works well for the lighting conditions of the vehicle during a drive, which can vary from fairly light to often shaded and even dark. The automated dimming and brightening of the screen based on the surrounding light conditions could also prove a useful feature, much like how many laptops react to the lighting conditions of their environment. As an incidental observation, car interiors tend to be dark too, so a colour-match of the car’s interior and its UI could also be considered when attempting to blend the two, something we’ve already communicated a great interest in.

MIT AgeLab and Monotype have paired up to tackle the issue of typography specifically for the in-car HMI. Find out more about this here and in this talk.

COLOUR: BEAUTY & BRAINS

Tim Smith
Design Specialist
ustwo

As we researched the car UI landscape and what had been before, we realised quite quickly that they all looked pretty much the same.

They were mostly dark, moody, neon blue-accented, metallic textures, bezels, and shadows.

When we take a step back and look at the examples we've gathered, there is a strong feeling that many of the UIs exude a masculine feel, akin to the automotive industry as a whole, decades ago. In-car UI seems to be stuck in the past, whereas the rest of the industry has matured into an all-encompassing, unisex, contemporary space. We see a great opportunity to bring car UI up to date, enjoying the same maturity as the rest of the car. In so doing we have to go against what has been before.

The first thing we explored was reversing the dark background into a pale one. A paler UI tends to evoke notions of lifestyle, modernity, simplicity and approachability — exactly what we thought was appropriate to achieve our ambitions for our design. Darker backgrounds often evoke moody, masculine tones.

Volvo Concept Coupe

However, following some user testing and exploration, it appeared that this was perhaps not the correct direction after all. It seems there was a reason our research revealed so many dark car UIs. Dark backgrounds prove less distracting, provide less glare and are therefore, importantly, safer than paler screens. With that fundamental truth, we were confident we must switch to a dark background, but we still felt we could shed the common masculine, science-fiction aesthetic of so many other in-car UIs by making specific design decisions.

> *“Everything has a personality: everything sends an emotional signal. Even where this was not the intention of the designer, the people who view the website infer personalities and experience emotions.*
>
> **Don Norman**

Choice of colour was one way in which we could offset the gender bias. A charcoal grey or other dark colour rather than black can soften the overall look. We also carefully chose a palette of low saturation, but bright pale colours to neutralise any negative stylistic connotations — the opposite of the neon blues of many car UIs.

The benefits of the use of colour are not only in its look and feel, but also in what it can communicate and — importantly — how we can colour-code groups of information. Instead of opting for the familiar monotone colour scheme, we used a range of colours. This helped to brighten up the whole experience, but also, there’s the added potential for extra information in those colours. We used colours to group information into colour-coded screens that each represented different categories of information. For example, a blue colour palette was designated to the media player screen, while a green was the colour scheme of the eco information and performance screen.

At a glance, the colour palette helped denote the screen and therefore orientate the user. In our concept, colour-coded information even helped create a relationship between two or more screens and enhanced understanding.

Colour is a powerful way in which to give personality to a design, be it a masculine tone or a friendly tone, something we used to great effect. Colour also carries great informational power; it can code, group, signify and prioritise pieces of information. But colour isn’t the only tool in our armoury that holds these dual emotional and informational abilities…

GROUPING & THE GESTALT EFFECT

Tim Smith
Design Specialist
ustwo

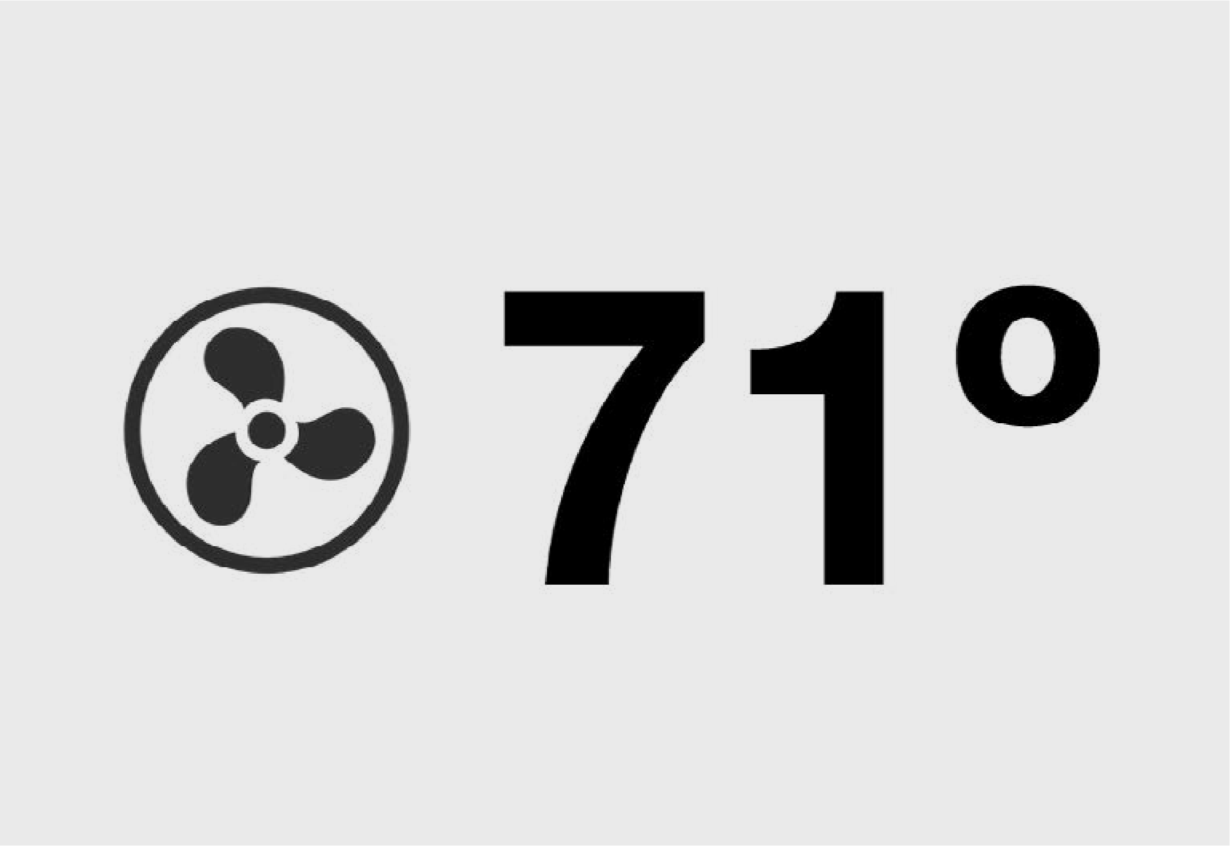
Further to colour and semantic skeuomorphism, grouping is another way to empower information.

The selection and confinement of information to one instance, such as a screen can shed light on and contextualise surrounding information by mere proximity.

This is supported by Gestalt psychology, which theorises that our senses have the capacity to understand an image as a whole, particularly with respect to the visual recognition, as well as the collections of parts it comprises.

This is known as the Gestalt effect. Imagine a fan icon on its own. What would that mean? Probably cooling or heating. Now imagine the metric 71° on its own. What could that mean? What is at 71°? The temperature outside the vehicle? Inside? Put the two together and you immediately understand 71° is the requested in-car temperature. The two pieces of information make sense of each other.

The Gestal effect makes sense of all the information



‹
2015 Audi TT HMI with air-conditioning fans

The 2015 Audi TT HMI uses the same principle, displaying this information right on the air-conditioning fans.

We opted to display information in simple, chaptered groups. Each aspect of function had its own designated screen, each with their own contextual pieces of information and colour scheme. We had a music player screen, an eco drive and performance screen, navigation screen and so on. By grouping the information in such a way, drivers were consuming just one type of information at a time, performing just one function, and were able to understand the different elements of information on the screen more quickly.

We also considered the positioning of the screens, as well as other hardware and physical elements of the HMI. Their positioning made sense of their function, visually and ergonomically.

USER TESTING

Barnaby Malet
Lead Developer

David Fisher
Interaction Designer

Tim Smith
Design Specialist

Harsha Vardhan
Interaction Designer

We recorded our user testing to study later

We hold ourselves to a high standard at ustwo and we had to ensure that we delivered, not only for the client, but for what's best for the user and driver.

We were building a complex system, but we were also defining new and unique interactions that people had never experienced.

To guarantee the result, we grounded all of our work in user testing. Our process resembled that of a fast-moving start-up where short design and development sprints are followed by user testing sessions and lessons learnt from these steer the following cycle.

With UI, UX and those physical principles involved in a HMI in mind, and designing for the in-car context, we derived the term '3ft experience', a derivative of TV's '10ft experience'. We used this as a guide in user testing to measure legibility of information and usability of interactions.

If the user could understand the information from the seat of the vehicle, roughly 3ft away from the UI, then its scale and contrast was adequate; it was legible (using traditional AA accessibility standards and our own PPP). Through trial and error, we came to the conclusion that, given the minimum scale and quantity of information one can digest within short dwell times, displaying just three pieces of information per "group" was appropriate: one primary and two secondary items, specifically for the driving experience. These rules could vary depending on contextual empathy.

We always presented primary information in the same spot on each screen so that the driver learnt where to look from screen to screen. Secondary information, which was treated sparingly, surrounded this. This works within the muscle memory, learnability and positioning principles discussed earlier. We found that people were quickly learning to default their focus to the same area of the screen. In doing that, we swapped more relevant information into this spot as we learned what was more useful to the driver in different situations.

Treating touch interactions in a similar way is something we also focussed on. One such method is best exemplified in Matthaeos Krenn's A New Car UI concept, which works within the same one-function-per-screen paradigm. Krenn's concept encourages a similar "blind interaction" method to the one we explored with gesture based inputs, interactions with affordability — agnostic to precision afforded by visual reference. As with physical gestures, there's some initial learning upfront, but so was there when swiping to unlock your smartphone was introduced. In time new interactions become second nature.

Interactions should support a micro-dwell approach, through colour, contrast, brightness, scale and affordability. The topic of dwell, and more specifically micro-dwell, is an important one which we considered carefully when conceiving, designing, prototyping and testing features for our concept.

Throughout the project our process kept improving; the testing moved from in front of a laptop to a 1-1 scale model of a car cockpit, and the cycle time shrank from over a week to two days.

By the end of the project, we'd tested the experience with over 30 individuals in a close-to-real setting. And in doing so seen it evolve from something obscure and complicated to something seamless and delightful.

> *"New controls can open doors for exciting innovation… but they also come with their new challenges that need to be respected and overcome.*
>
> **Matthaeus Krenn**

OUR EXPERIMENTAL PLATFORM

Barnaby Malet
Lead Developer
ustwo

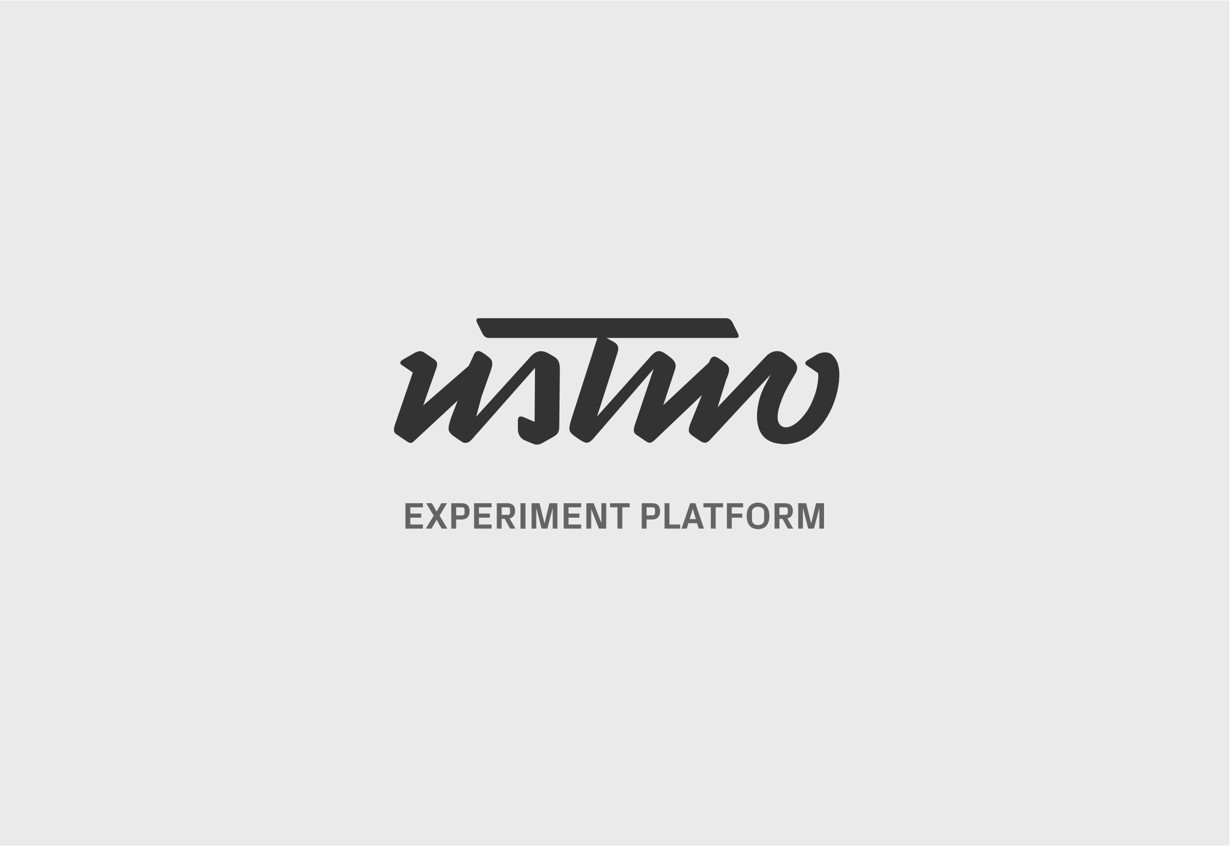
ustwo used the approach we previously formalised to construct an experimental platform for the project.

The platform was used to provoke questions and think about new paradigms in HMI with respect to a hypothesis / design statement, which evolved over multiple conversations with the client:

"How might we utilise the opportunities that come up when we move away from thinking about cars as tools and extensions of human function, to thinking about them as sensory and reactive entities, which can perceive and react meaningfully to the world around them?"

This concept is gaining credence due to present day research and development into human machine interactivity — which is bleeding into consumer technology.
For example, the idea of a smart, intelligent home being driven by Nest.

The ustwo experiment platform was used to provoke questions and think about new paradigms



1962 Ferrari 250 GT SWB
California Spyder

In the course of building on this design statement we explored concepts with respect to:

1. In-car computer vision to detect physiological and gestural data.

2. The car as an ambient agent offering meaningful aural and visual feedback based on the data it senses.

3. New principles with respect to data visualisation guiding interactions and visual design in screens.

4. Qualitative user testing with low to high fidelity prototypes which were used to iteratively validate and humanise the experience. Traditionally, you clearly define what it is a client will be paying for before any production work begins. But the amount of technical uncertainty on this project made estimation close to impossible.

So to de-risk our promises, the design and engineering teams came together to quickly evaluate what was achievable. And over the course of weeks into months, we continuously turned dozens of ideas into functional prototypes.

These prototypes, although basic, allowed us to present the client with a set of possible options that we knew we could deliver. We agreed on a subset, and set out to transform the most promising of these early prototypes into rich and contextually empathetic in-car experiences.

TOMORROW'S IN-CAR HMI

Barnaby Malet
Lead Developer
ustwo

Google's self-driving car

To understand what tomorrow's in-car software might look like, we turned to yesterday's.

In the past, we've seen technology move from homes and offices to cars (think digital audio, touch screens and mobile Internet). Today, technologies such as the Microsoft Kinect, Leap Motion and Myo are allowing computers to gain a stronger awareness of the user.

We designed the car with the belief that in the future, sensors like these coupled with advances in AI will fundamentally change the human–machine interaction model.

And tomorrow's homes, offices and cars will understand and adapt to us in a way that no computer does today.

Today's consumer sensors foster rich ecosystems which make them perfectly suitable for rapid prototyping. However, they are not designed to operate in the challenging environment of a car cockpit and are less reliable and more error prone in that environment. ■

Photo credit:
Otis Blank for Petrolicious

CONCLUSION
WHAT LIES AHEAD?

CONCLUSION

> *“Designing to gain trust is an amazingly interesting design challenge—far different from the technical problems.*
>
> **Paolo Malabuyo, Vice President of Advanced UX Design at Mercedes**

We are truly excited about the future of HMI in cars at ustwo.

Automobiles as tools have always been known to be ‘extensions’ of human faculties and we are now entering into an exciting new paradigm with the addition of intelligence into these tools — opening up a new world of possibilities.

With connectivity, near-unlimited access to information, pre-emption and efficiency that the digital age brings to a car, we feel that one should not forget the primary experiential qualities — the nature of the drive, safety of passengers and fellow travellers, and, most importantly, the pleasure of travelling and being at one with a vehicle.

Technological ‘extensions’ also bring about ‘amputations’ — for example, the telephone extends the voice, but also amputates the art of penmanship gained through regular correspondence.

USTWO WOULD LIKE TO LEAD THE WAY IN CREATING A HMI THAT IS FUNCTIONAL & BEAUTIFUL.

In working with HMI we should make sure we are not amputating something fundamental to the experience of using a car. We believe that car manufacturers need to adopt new approaches if they are to stay ahead of rapidly changing technology, its impact on design and user experience, and integrate it into their legacy manufacturing cycles.

The connected car approach presented by Apple and Google is a possible short-term solution which hands over the platform to an external device, but there's an opportunity for car makers to take this further and explore new interaction paradigms of their own. Investigating these paradigms might answer larger questions — like is there is an argument for HMI to be completely non-visual, opting instead for audio and haptic feedback as well as vocal and gestural input?

Let's think strategically. What will the world look like following Tesla's announcement about open-sourcing their technology? What will we stand to gain from the emergence of truly connected cars or 'radically connected' as coined earlier in this thought piece?

With the deep integration of internal telematics and infotainment systems to the web, from the ground up rather than as an afterthought, the possibilities are endless.

Beyond understanding technology, another factor unique to interactions within a car, or at least at a much greater priority than of most, is trust.

Compared to a smartphone, if a car fails the consequences are much more considerable — and people are very much aware of this. Gaining a driver's trust with truly revolutionary driving features is a hurdle that will need to be overcome. Features such as automated driving and the engagement of safety features and how they relate to the HMI will be a huge challenge.

To conclude, we believe that disruptive innovation requires a new approach, and in our experience a 'lean start-up' and an entrepreneurial team using rapid prototyping is what's required to keep pace with technology and user expectation. And that might just be ustwo. ■

A BIG THANKS TO...

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To the ustwo famps for their support throughout the process.

ustwo