

A First Approach to Understanding and Measuring Naturalness in Driver-Car Interaction

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ABSTRACT

With technology changing the nature of the driving task, qualitative methods can help designers understand and measure driver-car interaction naturalness. Fifteen drivers were interviewed at length in their own parked cars using ethnographically-inspired questions probing issues of interaction salience, expectation, feelings, desires and meanings. Thematic analysis and content analysis found five distinct components relating to ‘*rich physical*’ aspects of natural feeling interaction related to richer physical, analogue, tactile styles of interaction and control. Further components relate to humanlike, intelligent, assistive, socially-aware ‘*perceived behaviours*’ of the car. The advantages and challenges of a naturalness-based approach are discussed and ten cognitive component constructs of driver-car naturalness are proposed. These may eventually be applied as a checklist in automotive interaction design.

Author Keywords

Automobile; contextual inquiry; humanlike; meaning; naturalness of interaction; qualitative thematic analysis.

ACM Classification Keywords

H.5.2 [Information Interfaces and Presentation]: User Interfaces – *Interaction styles, Theory and methods, User-centred design.*

INTRODUCTION

Transport research has suggested the car fulfills three roles: instrumental, symbolic and affective [48], but the meaning-based and emotional aspects of driver-car interaction have not always been considered as fully as the technological issues [20]. Cars increasingly exhibit *pervasive computing*¹ [44], autonomous safety and self-driving abilities [38], potentially changing the driving task fundamentally [4].

Some evidence suggests that drivers’ current user experience often falls short of ‘natural’ [32, 39, 44]. Despite multiple technological features [35] some drivers appear to desire simpler, more ‘natural’ car interfaces [50]. However little research exists on what characteristics or features make a car *feel* natural or unnatural when interacting with its various controls.

This study was conceived to explore how ordinary drivers perceive ‘natural’ driver-car interaction in order to develop measurement scales to assist in designing more natural-feeling driver-car interaction in the future. Increasing *naturalness of interaction* (NOI) may also improve acceptance, user satisfaction and sense of ‘emotional safety’ [21] in future semi- or fully autonomous cars.

Most driving controls are now to some extent electronically mediated - few *direct* links exist between the driver and the car’s mechanicals. Much modern digital driver-car interaction is arguably a form of moving human-computer interaction. In [35] it is argued that “*Contemporary cars are often cluttered with buttons, knobs and touchscreens*” causing “*a high level of mental workload and distraction*”. Vehicle feedback and ‘feel’ have been shown to play a key role in driver safety and satisfaction, yet both have been steadily reduced since the 1990s [52].

The meanings [8] drivers attribute to automotive controls have rarely formed an explicit research goal since 1966 [6]. Occasional recent work has concerned perceptions of advanced car safety systems e.g. [30, 51]. The car has arguably been rather neglected in sociological and anthropological research too [36]. Considering driving as a *user experience* (UX) [50], or *intelligent interaction design*, rather than simple human-machine interaction, may offer useful insights. A small but growing body of research in the last five years indicates that qualitative approaches such as ethnography [47], observation, and *contextual inquiry* [5] have a valuable complementary role to play in automotive interface design [35, 18].

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¹ A vision for computing in which devices, software and services seamlessly integrate and cooperate in support of human objectives, in an ‘anywhere’, ‘anytime’ way [11].

Interaction naturalness has been variously interpreted by non-automotive design researchers as meaning richness of interaction e.g. [29]; physical/bodily interaction e.g. [27]; mimicry of some measurable property of the natural world e.g. [23]; or mimicry of some familiar human action *on* the world [28]. None of these interpretations has apparently yet been systematically applied to cars. The similar sounding paradigm *natural user interfaces* [54] has been considered in relation to cars but its preoccupation with gesture appears to have fundamental limitations in cars [33].

While in theory it is possible to design physical driver interfaces that feel more ‘natural’ to the average driver, naturalness may be better understood as a property *of the interaction* not just the interface [40]. Interaction is only ‘natural’ in specific temporal, physical, or emotional contexts. Thus automotive NOI may be better understood as *natural-feeling* interaction [40], akin perhaps to that felt by a concert violinist playing their favourite violin [54].

An extensive literature review defined the terms of automotive naturalness of interaction (NOI) as follows:

1. NOI applies *to the interaction*, not just the interface: naturalness is *the feeling the user should have during an interaction*, and is a property that emerges through use.
2. ‘Natural’ interaction is typically interpreted as interaction that feels instinctive, intuitive, direct, relaxed, innate, familiar, expected, bodily situated or minimally processed.
3. NOI should be grounded in ethnographic observation of drivers’ actual behavior as well as ‘think-aloud’ probing, in-depth interview and discussion, to elicit consciously and subconsciously attributed meanings.
4. NOI concerns any functional, symbolic, emotional, metaphorical or personified interaction between driver and car and includes direct or supervisory control of a car’s primary, secondary and infotainment functions. Driving is a unique physical reality-based interaction.
5. In anticipation of future highly intelligent cars, NOI may include perceived ‘intelligent’ interactions and relationships akin to those between intelligent beings.

In our studies, drivers interpret ‘natural’ interactions as they see fit and are not prejudiced by any definition other than such interactions being ‘natural-feeling’ to them.

AIMS AND OBJECTIVES

The current study aimed to discover what the characteristic components of NOI might be in an automotive context, using principles of *contextual inquiry* [5]. NOI themes were explored *explicitly* through in-depth semi-structured interviews probing drivers’ memories and visualisations of natural-feeling automotive interactions, and the data then ‘mined’ (using a controlled degree of psychological interpretation) for any *implicit* perceptions, desires, phenomena and expectations possibly related to driver-car

NOI. In view of the lack of existing literature, an inductive approach (*grounded theory* [22]) was taken without resort to existing frameworks other than the definition above. The research follows the paradigm of *human centred design*.²

METHOD

Qualitative research is about subjective experience and coherent internal narrative [10]. It is not used for generalisability and is considered ‘saturated’ when no new verbal ‘codes’ arise [34]. It was decided to conduct in-depth interviews using the ‘n=12+3’ sample size principle, whereby 12 interviews are fully analysed and three more then conducted to check no *new* codes or themes arise; it has been suggested this often achieves saturation [3, 25].

Content analysis (CA) and *thematic analysis* (TA) were identified as qualitative analysis methods suitable for interpreting, summarising and presenting interview data [9, 16]. TA has been successfully used in qualitative car studies before e.g. [10]. Fundamental to the theory of CI is to interview and observe people in their normal operating environment [5, 12]. Thus all interviews were conducted in interviewees’ own parked cars (moving cars having been ruled out for safety reasons). Following [49] the purpose of the research was kept unclear.

Study Design

A sampling model [13] was established, based on existing researchers’ profiling of drivers. As a pilot exercise to conceive the interview questions, four drivers were asked to speak freely about the car-related NOI themes found in the literature review. These interviews were fully transcribed and subjected to basic TA to reveal likely naturalness-themed perceptions and phenomena.

Thirty-two possible interview questions were conceived with reference to the ethnographic interview styles of Spradley [47] and Osgood [41], balanced evenly between the two. All questions were ‘open’ so as to achieve richer narratives. They were guided towards actual past experiences, feelings, visualisations and meanings around driving and car controls. Interviewees were not prejudiced directly with the semantic ‘natural’ for the initial two-thirds of the questions (instead questions for example probed ‘direct’ or ‘ideal’ interactions) but they were deliberately primed with five typical driving scenarios on which to reflect upon. While most questions related to past or recent interactions, future-focused questions encouraged drivers to visualise detailed personal ‘future fictions’ [19] to help discourage ‘theoretical’ socially-mediated responses [13].

A pilot study of six drivers took place in Oxford, England after which 29 final questions were selected following ‘debugging’ to remove misleading, misinterpreted or

² A multidisciplinary design approach aiming to enhance human well-being by creating systems, machines, products and services which are physically, perceptually, cognitively and emotionally intuitive to use.

unproductive questions. This was achieved by negotiation between first and second authors using the pilot study transcripts. The initial section of questions probed car-related expectations and system/feature saliency. Central questions asked about natural-feeling interaction in a number of ways and introduced the five driving scenarios. More probing, visualisation questions were reserved until the end, when participants had appeared to be most relaxed and frank.

Interviewees were recruited through adverts in social and professional networks, and two car clubs, in Oxford and Uxbridge, England, asking for details of car type, typical car use and driver age. A sampling model derived from the literature review was used to represent all six common car classes (e.g. premium, sport, SUV) and each of the seven user types (e.g. high milers, enthusiasts, occasional users) in the chosen 15 drivers. A 'hybrid' car driver and a 'city car' owner, still rare on Europe's roads, were included to represent future trends. No payment was offered.

Procedure

1. Interviewees were greeted, the format explained and a consent form signed. A brief preamble was read out.
2. An impartial but friendly, supportive approach was adopted because it had seemed to yield the most in-depth and unguarded responses in the pilot phases.
3. Interviews took place in safely parked cars. In total 10 men and 2 women aged 30–70 (mean=48; SD=14) were interviewed (mean interview time 37 minutes), followed by three further males to check no new codes arose.

DATA ANALYSIS

The aim of the *content analysis* (CA) was to distil keywords relating to driver-car NOI into fewer content-related categories [16] and to make patterns in the data clear. The *thematic analysis* (TA) built on the CA in a more interpretive way to provide an 'illuminating description' of any possible naturalness-related phenomena [46]. Well-established guidelines were followed (especially [9]). A matrix framework approach [46] was also used to draw the CA and TA findings together and gauge *strength of feeling* by comparing codes and themes mentioned once *vs.* multiple times. The actual process was as follows:

1. The interviews were transcribed in full including expressions and pauses, then read three times to identify semantics and meanings possibly related to NOI. The question borne in mind was "What are they really saying?" [37]. After comparing transcripts person-by-person, responses were compared question-by-question.
2. The transcripts were then trial coded at a basic semantic level, and codes combined where there was a dictionary simile. Possible higher order (interpretative) NOI themes, patterns and potential groupings for the codes were noted in the margins.

3. Each code and theme was checked against the dual criteria of *internal homogeneity* (whereby data within a theme are meaningfully coherent and the same) and *external heterogeneity* (whereby each theme is logically distinct [24]). Some codes were reworded.
4. A fresh transcript of every interview was fully coded with keywords for individual codes and six colours of highlighter pen for the common theme groupings.
5. The logic of all codes and themes was discussed and verified with an independent psychology researcher [31] and a 'blind' CA of three transcripts conducted by another member of the research team. Resulting minor coding amendments were then applied to all transcripts.
6. A bespoke database was created in Microsoft Excel and summary codes and themes entered and counted. Themes not shared by at least 30% of participants were generally ignored [9]. Codes were helpfully 'named'.

RESULTS

By grounding the analysis in direct quotes from the participants, the researcher's interpretive role was kept relatively transparent [9] Quotes are therefore included in the results below with indication of interviewees' gender, age and car type (e.g. "F 35-50 Premium") for context. No new codes were found in the three further 'check' interviews conducted after the initial 12 were analysed. The results presented below are of two types:

- A. The relative **saliency of driver-car input and feedback interactions** (a possible indicator of what *features* and *systems* might feel natural), from the CA.
- B. Five apparent **physical and control interaction characteristics** of natural-feeling driver-car interaction, and five apparent **social and intelligent perceived car behaviours** characteristic of natural-feeling driver-car interaction (the latter mainly concern intelligent/future cars). Both were derived from the Thematic Analysis.

A: SALIENCY OF CAR SYSTEMS AND FEATURES DRIVERS ASSOCIATE WITH INPUT AND FEEDBACK

The number of times drivers mentioned car systems or features they associated with input or feedback interaction, across the whole dataset, was calculated as a measure of saliency and expectation, likely to be important in NOI. As far as possible common cognitive biases [7] were checked and controlled for in the questions, analysis and interpretation. The classification as 'input' or 'feedback' is the drivers' own and does not always appear logical, but may provide insight into underlying perceptions. For example a commonly cited driver *input* to the car was 'visibility' whereas 'braking' ranked quite low. The low salience of safety systems generally may be an example of the 'say-do gap' noted in automotive interviewing which may downplay less immediate issues compared to subsequent or actual behaviour [15, 26].

Most frequent driver <i>input</i> semantic codes mentioned	% of drivers who mentioned it	Average mentions per person
1. Potency & manoeuvrability	90	2.3
2. Transmission	85	1.7
3. Music or radio	80	1.6
4. Steering	75	1.6
5. Comfort systems	75	1.4
6. Braking systems	75	1.3
7. Visibility	65	2.0

Table 1. Commonly mentioned ‘input interactions’

Most frequent driver <i>feedback</i> semantic codes mentioned	% of drivers who mentioned it	Average mentions per person
1. Constant sound & vibration	90	2.6
2. Gauges	85	3.2
3. Warning lights	60	1.5
4. Steering feel	55	1.5
5. Graphical displays	35	1.3

Table 2. Commonly mentioned ‘feedback interactions’

The full ranking of relative mentions of input and feedback interactions is presented in the tables above. Feedback was generally interpreted more logically and predictably.

B: THE PROPOSED COMPONENT CONSTRUCTS OF NATURAL FEELING DRIVER-CAR INTERACTION

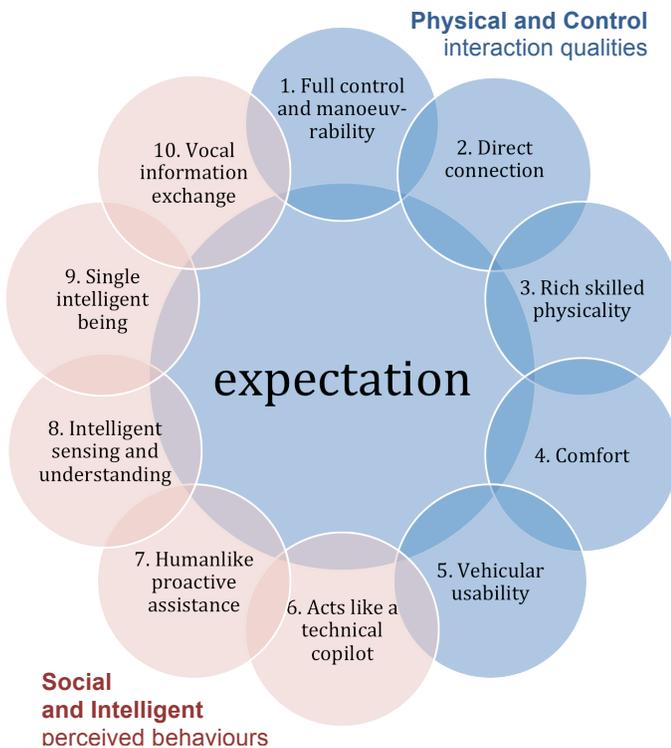


Figure 1. The 10 Constructs of Driver-Car Interaction Naturalness

Constructs 1 to 5: Physical and Control Characteristics

1. Full Control and Manoeuvrability

A group of interrelated themes concerned overall control and manoeuvrability of the car. The way they were expressed suggested they were deeply implicated in natural feeling driver-car interaction. Most drivers expected to feel in full control:

...most of the time I feel in full control of the car. And I'd be worried if I didn't. M 40-45 Premium

When asked to explain what full control *felt* like, the general semantics arising were those of flow, mastery, human-machine unity, and positive contextual factors:

I think I feel in full control when I'm on an open road with little traffic and I'm rested, I'm not hungry, I'm not thirsty. [...] no jams, the car was behaving perfectly. M 65-70 Premium

Perhaps paradoxically, ‘autopiloting’ was a commonly cited phenomenon, and apparently not unrelated to NOI:

It's all reflex actions... like riding a bike... M 40-45 Premium*

Potency and manoeuvrability appeared more desired than absolute speed in NOI, along with good visibility.

...To duck in front of a bus next to me... M 30-35 Premium

Examples of unreliability, loss of control or traction, lower than expected potency, the car taking control, and minor or major mechanical failure, were expressed very often and invariably very negatively:

Oh, reliability. If a car lets me down then it's really got a big black mark against it and it only has one more life left. It's a bit like... if an animal [...] attacked you. M 40-45 Premium

... I couldn't stop it, I couldn't turn off the cruise control [...] that frightened me to death really... M 65-70 Citycar

2. Direct Connection

Constant mechanical (sonic/vibrational) feedback appeared to be perceived as both natural and desired. Steering also acts as a useful ‘natural’ sounding stick to the road ahead:

Just by the feel of it and the noises. [...] I'm definitely one for spotting a peculiar noise sometimes and you think 'hang on a minute that's not right' F 45-50 Premium

You're feeling how your car is holding the road, you're reacting to bumps and feeling through the tyres through the steering wheel.... M 40-45 Premium

Stop-start systems, which save fuel when cars are stationary for short periods by cutting out the idling engine, arose in several interviews as an issue of some concern. The lack of reassurance the car would restart, the ‘unnatural’ silence and lack of vibration appeared to undermine the naturalness between driver and car:

... I need it to keep running [...] I just need to have the comfort it's just purring away and ready to go. M 40-45 Premium

Gauges appeared to provide a form of ‘natural’ mechanical connection to the car e.g. temperature, economy or engine speed:

I do keep a fairly good eye on the temperature... I do like to have a physical gauge to see what's going on... M 40-45 Sports

There was some naturalness-related reminiscing about ‘temperamental’ cars of the past (despite the modern expectation of reliability above) perhaps due to the closer ‘connection’ with the mechanicals of these older cars:

...the romance of driving at a time when... you were much more in contact with... you could service your own car [...] it was more possible to give the car a personality then [...] there was a feeling that if you treated it nicely it might be nice to you M 65-70 Premium

Overall it was difficult to discern whether the ‘direct connection’ was to the car’s mechanicals, or the road, or both, thus the title of this theme reflects a general ‘reality-based’ physical connection.

3. Rich Skilled Physicality

There was enthusiasm in descriptions of rich physical, analogue, skilled control inputs such as steering and cornering, which appeared highly natural but require complex learned skill:

I just got the knack of it of doing it really well and it just feels like you're really masterful [...] that really fine balance [...] it gives you a real sense of exhilaration almost. M 40-45 Premium

I mean I have driven cars where [the power steering feels] completely disconnected and that doesn't feel right to me, that feels like playing a computer game... M 40-45 Premium

Transmission was mentioned often but in a rather passive way compared to analogue inputs like steering and, apart from clutch control, was typically described as a ‘mode’ they ‘put the car in’:

It's an automatic so obviously I'd use the gear selector to put it into Drive... the normal position it sits in. M 40-45 Premium

Overall this theme encompasses a sense that precise, weighted analogue, physical interactions felt more natural than digital ‘clicks’, lightweight-feeling interaction or binary mode selections. Inherent was also a sense that natural interactions had an instant, closely coupled ‘cause-and-effect’ relationship of the driver acting on the ‘real world’. This led to a sense of ‘craft’:

Driving is a craft, and I quite enjoy crafting... M 40-45 Sports

4. Comfort

The most mentions of any individual expectation semantic related to comfort – typically adequate comfort of seats, and maintaining appropriate of internal cabin climate, especially ventilation.

When I proceed I'm very comfortable. I do like the controls up here on my wheel. M 70-75 SUV

It feels a bit like I'm still at home, because I'm comfortable in my car, and I've only recently got out of bed. M 35-40 Luxury

Included in this ‘comfort’ theme were related semantics about ‘minimum fuss’ and ‘ease’. Comfort expectations like music, radio and climate, had high saliency and associated ‘feeling’ and therefore might be assumed to be NOI-related. Drivers may also enjoy controlling them:

The air conditioner [...] and the radio I guess [would be the most important interactions]. Coz you're playing with the radio, playing with the air conditioning... M 30-35 Sports

About a third of drivers considered their car a haven or sanctuary from their everyday life or the world at large, often enhanced by control over their music and climate:

A haven of being alone with myself, and being able to shut out the world... M 65-70 Premium

A deep discomfort appeared to exist around being stranded or humiliated on the road (especially holding up other traffic) and this is included in this theme in the sense of ‘social comfort’.

...and in the middle of the road it's like STOP, stopped still, and you'd be causing havoc in the traffic [...] I just felt really frustrated, embarrassed, annoyed really. F 45-50 Premium

5. Vehicular Usability

Good visibility is a key expectation and driving phenomenon, and related to being in control. Although vehicular ergonomic preferences were not probed in detail, this theme encompasses an apparent naturalness preference for vehicular usability heuristics such as eyes-free operation of controls and minimal distraction, but needs to be explored more explicitly in future studies.

Constructs 6-10: Social-Intelligent Perceived Behaviours

6. Acts Like a Technical Copilot

In this theme, many drivers described a businesslike partnership, or copilot-type relationship (pragmatic, subordinate but respectful) when describing natural-feeling interaction with current or future cars:

I see it as a partnership [...] I wouldn't get there without the car, and it wouldn't get there without me [...] I don't mollycoddle it, I expect it to make progress... M 40-45 Sports

..It would actually be very handy to be able to bark out instructions [to the car] as if you had a co-driver M 35-40 Luxury

The style of relationship described was factual, formal, concise and polite. There was often an unspoken sense the car was ‘younger’ than the driver. If their future car could ‘talk’, drivers would expect it to talk about its area of expertise, e.g. economy and mechanical health, preferably

in a richer way than current ‘check engine’ lights. This too suggested a ‘copilot’-type character of the ‘natural’ car.

It would give you more current feedback if there’s something out of line, a belt’s loose, radiator fluid needs topping off... M 30-35 Sports

There was a sense that the car could be trusted to get on with certain jobs that it did best, for example this quote from the hybrid car owning interviewee:

The time it takes control of itself is the time it switches between power sources. Without a doubt. [...] [it feels] quite pleasing. It’s taking actions for the right reasons I suppose. M 45-50 Hybrid

7. Humanlike Proactive Assistance

This theme achieved over five unprompted citations per person per interview, more than twice as many as any other intelligent car theme. This theme was exemplified by the future natural-feeling car taking some definite action or offering assistance based on information it had sensed and processed itself. This theme does not include automation of the primary controls, which was rarely expressed in natural-feeling terms. Examples include doors opening and unlocking, climate adjusting to usual settings or body temperature, and seats moving into helpful positions. The theme of driver recognition was implicit to most of these:

...it will have sensed that you’re walking up to it, the door will open, the steering wheel will move out the way, the seat will move right back [...] the seat belt will do up for you, the car will start, it will have checked all its stuff around it... M 65-70 Citycar

It tended to be repetitive, ‘clunky’, inevitable tasks that were described as automated. Most drivers appeared wary of self-driving cars and would find them very unnatural, at least to begin with. Many drivers said they were generally much happier to drive than be driven, and that they would dislike being driven by an automated car as much as they would by any person. Most seemed well aware of the classically documented problems of automation [45] e.g. failure and overreliance. Humanlike intelligence and perception in car actions, automation and feedback appeared to be perceived as more natural:

To me something that’s automatic should be completely automatic, it should sense when YOU might decide to put your lights on. M 65-70 Citycar

Natural feeling assistance should therefore mimic the actions of a competent yet confident human in that same situation, and not add the ‘cognitive overhead’ of having to supervise the automation:

The lights in this car [...] go on automatically, which I like, coz I don’t have to think about it. But occasionally I get people flashing me and I wonder if it’s done the wrong thing. M 35-40 Luxury

...cruise control is uncanny because it does keep the same speed even when you go down a hill and into a dip and then up the other side [...] if you were just using your own brain to control the car, you would be going more slowly up the rise than you were coming down! M 65-70 Premium

8. Intelligent Sensing and Understanding

Most interviewees described more natural feeling cars as having better sensing. This theme was defined as the sensing of environmental, mechanical or contextual parameters, and presenting the information to the driver, but *not* processing it nor taking action.

I guess [I expect] more of an intelligent computer system inside the car and more sensors to be aware of what’s happening inside or outside of the car. M 30-35 Sports

Gauges were very salient and may be perceived as more natural feedback than ‘binary’ warning lights and were mentioned by each driver more than three times on average. Warning lights were quite salient but appeared to be perceived as less ‘natural’. Graphical displays appeared potentially natural-feeling in a car. The few drivers who had them described them very richly and positively.

Instances where cars’ automation had resulted in social signals or actions contrary to the driver’s intent, or presented irrelevant options, or misunderstood the context often caused anger and were potentially perceived as ‘unnatural’ interactions:

The car can’t tell that you’re picking someone up. And they open the handle and look at you in a very aggrieved fashion! That’s irritating because the car is making you behave discourteously! M 65-70 Premium

Therefore the word ‘understanding’ was added to the theme to reflect this contextual awareness and ‘sentient’ comprehension of social factors in and around the car.

9. Single Intelligent Being

Drivers often did not perceive present day driving interactions as being inputs to a single ‘whole car’. Driving was often expressed as the adjustment of multiple ‘on-board systems’.

You have to use the two or three pedals to go forwards or backwards as the case may be, and I suppose every car has a steering wheel. M 40-45 Premium

This appeared to undermine the naturalness of the interaction, when a more psychologically interpretive analysis was made of the data. Only after that coordination of multiple systems becomes habitual and almost unconscious, does driving as a whole feel ‘natural’.

The modern car has, in one participant’s words ‘no soul’. No one expected their car to be able to make truly humanlike conversation or give the impression of free thought. Although some human attributes would be

welcome, the car was often described as neither pure machine nor pure ‘being’, but rather a hybrid of the two:

... you do want your car to feel as though you appreciate it, because in that way you hope it won't let you down. And I know that's irrational [...] you almost tap the dashboard and say 'well done, thanks' ... M 30-35 Premium

The most intelligent part of the car was usually said to be the engine or the engine management system. The engine was also often the ‘heart’ or ‘lifeblood’ of the car. Such biological semantics arose occasionally. There was a suggestion from a few drivers that a natural feeling car should have a single ‘voice’ or ‘ears’ and consistent intelligence across all its systems. The car’s intelligence was often likened to a very ‘functional’ intelligence:

It's a kind of dispersed brain, across the dashboard, and all of these controls, there and there, it's like a sideways L-shape. [...] it's not a cohesive brain like a human brain...

M 35-40 Luxury

10. Vocal Information Exchange

There was a fairly common theme of the driver wanting to invoke, set or adjust a particular feature by voice, both for current cars *and* future cars, described in natural-feeling terms. It often involved a direct command and the vehicle responding by action rather than voice. Examples were music selection, GPS destination entry, and climate setting. In *future* natural-feeling cars, the theme ‘Intelligent Exchange By Voice’ was more common whereby a driver described a *non-command* style two-way dialogue, not resulting in any direct or instant action, instead contributing to an overall intelligent ‘dialogue between sentient equals’:

The dashboard would say 'good morning' and 'where are we going to today' and 'what time do you hope to arrive' and you'd say back to it 'we're going to Holborn' [...] and it would say 'certainly' 'sit back, relax...' M 65-70 Premium

Other examples of this theme include the car offering information about road conditions and “Are you ready?”-type questions. The overall impression was one of easy, polite, seamless exchange. Usually voice was implied, but some examples could feasibly be interpreted as text-based. Drivers would apparently ‘naturally’ talk either to their dashboard or steering wheel.

Whereas all the other themes listed above arose largely unprompted and unprejudiced in the interviews, three of the later interview questions explicitly concerned the ‘talking car’ (because in the pilot interviews it had been observed to be a good ‘proxy’ for eliciting the relationship with the car). The listing of this theme at the end of the Results is therefore indicative of the possible prejudicing that led to it.

DISCUSSION

It is hoped that the Naturalness Constructs above might eventually be developed into a **design checklist** for use in the automotive industry when designing driver interactions and user experience, throughout the whole design process. The Constructs would be abstracted in ‘layers’ of an ‘information hierarchy’ according to design need, from a two or three word summary catchphrase (e.g. for branding teams and interior architects) to a whole sentence giving more detailed explanation and applicability of each Construct in order to avoid subjective misinterpretations (e.g. for ergonomists and programmers). It will be important to reference the nuances and meaning in drivers’ *actual words* so as to preserve the original meaning. Accordingly the final layer of information (for those inclined to read it) would be selected quotes from the data showing the actual words of drivers that led to the creation of each element of that Construct. This checklist would permit a form of rapid ‘co-design’ allowing, by proxy, the ‘voice’ of ordinary drivers (regarding what feels natural) to be represented.

Alternatively, the Constructs might be applied in the form of a **rating scale** used to assess *existing* features with unexplained poor uptake, new features nearing launch not yet user-tested, or to help shortlist which potential new feature concepts to take forward to development – on the assumption that the more Constructs that are met, the better the likely uptake and acceptance of that feature and perhaps also greater satisfaction and emotional connection. The constructs could conceivably also be used as focus group questions or ‘car clinic’ rating criteria when user-testing new features, controls or even car cabin interior design.

Most of the **Physical and Control** Constructs (i.e. 1 to 5) would translate fairly literally into design form and function (e.g. comfort and vehicular usability) albeit requiring a certain amount of sympathetic user-driven interpretation in the case of the ‘experience design’ of the weight and tightness of controls as per Construct 3, and the extent and sensory mode/routing of the ‘connection’ to road and powerplant in Construct 2. Again, referring back to drivers’ original words should preserve the intended meaning. As a general guide, for example, it would appear that a driver interface characterised by physical levers and rotary controls, multiple degrees of freedom instead of binary ‘modes’, a tight/weighty precise feel, ‘*what you see is what you get*’ controls with closely coupled cause and effect, and gauges instead of warning lights, will feel more ‘natural’ to use.

Some of the **Social and Intelligent** perceived behaviours of the intelligent car (Constructs 6 to 10) could in principle be applied today on a superficial level (e.g. assistive seats and seat belts, a cruise control system that slows slightly uphill and speeds up a little downhill, a car that speaks with a single ‘voice’, and a copilot-like delivery of technical expertise and trustworthy performance of routine technical tasks) but their ultimate manifestation may have to wait

until technology is capable of executing it properly. For example, a voice system with natural language understanding and conversational ability, physical controls that rise up or disappear depending on context so the driver is presented with only meaningful options that are relevant at that time, and socially intelligent ‘sentient’ awareness of context, mood or intent. Indeed, these *socio-intelligent* examples of naturalness, where the car borders on being perceived as an intelligent being (as in [43]) arguably should be executed either perfectly or not at all: the data frequently suggest an ‘intelligent’ feature performing imperfectly is quickly perceived as rude, stupid or impolite (as in [12]) leading to disuse and creating far more anger and lost respect than if that car had made no effort at all.

The **value of a naturalness approach** over a traditional usability or ‘human performance’ ergonomic approach may be illustrated by considering stop-start systems. While such systems presumably satisfy basic heuristics of usability and safety, they clearly do not feel *natural* to most drivers. Comparing it with the 10 Constructs above, stop-start works counter to expectation, lessens sense of control, gives off confusing social signals, isolates the driver from their mechanicals and gives little clue it is proactively ‘ready and waiting’ to restart. A ‘naturalness’ derived improvement to stop-start design might instead synthesise engine vibration during engine cut-out, clearly indicate that it is indeed in ‘stop’ mode and not just stalled, and reassure the driver verbally, tactually or visually that it is ready to restart instantly the moment the driver wants it.

There may be **challenges to implementing** the Naturalness Constructs concurrently. Firstly, despite feel and feedback, evidently important in naturalness, being steadily reduced in recent years [52], the data suggests ‘direct connection’ is a ‘natural’ expectation but so too are the potentially contradictory desires for ‘comfort’ and ‘haven’. Refinements and efficiencies of modern cars have perhaps created a less visceral, less ‘natural’ relationship, but interviewees’ perception of steering feel as highly ‘natural’ now is interesting because that steering is power assisted and thus its feel highly mediated by electronics and actuators [2]. Perhaps then, there is potential to ‘synthesise’ naturalness. Secondly, some future highly automated driving arrangements may go against naturalness guidelines. However, with sensitive automation design such as the ‘horse-rider metaphor’ [17] or ‘haptic shared control’ [1], self-driving cars could still feel broadly natural because they would satisfy most of the physical Constructs and some of the social ones. Thirdly, drivers’ narratives around ‘autopiloting’ suggest automaticity, often viewed as a contributory factor in accidents [42] is in some ways ‘natural’, yet manufacturers are unlikely to want to encourage it. Fourthly a line needs to be drawn between ‘humanlike proactive assistance’ and ‘automation’. Too many weak ‘offers to assist’ could overwhelm a driver whereas the car perhaps just ‘getting on with’ certain basic tasks automatically may be preferable.

A further possible contradiction concerns the Naturalness Construct ‘Vocal Information Exchange’. This appears to contradict the reality that reported uptake and long-term use of car voice recognition systems are low [53] despite advanced systems having been available for 10 years or more. It is however argued that certain natural-feeling characteristics *desired* by drivers are usually lacking - such as perfect natural language understanding without ‘push to talk’ or learned ‘command’ vocabularies, the car’s ‘sentient’ ability to build up understanding through two way ‘conversation’ with improvised turn-taking, and a sense of politeness and social awareness. In many ways the type of voice system drivers described meets many of the Constructs in its own right, thus further research is needed to decide if Construct 10 is the ‘odd one out’, better understood as a *feature* that exhibits naturalness rather than being a Naturalness Construct in its own right.

CONCLUSIONS AND FUTURE WORK

Fifteen drivers were asked in depth about their interactions and relationships with their cars using ethnographically inspired interview techniques, in order to propose ten component constructs of driver-car interaction naturalness.

In conclusion, the data suggest that natural interaction occurs between driver and car when that interaction conforms to driver expectation like reliability, familiarity and avoidance of surprise and when its physical interaction exhibits qualities of (1) full control and manoeuvrability, (2) direct connection, (3) rich skilled physicality, (4) comfort, and possibly (5) standard vehicular usability heuristics, and where that car’s intelligent features are perceived to: (6) act like a technical copilot, (7) assist in a humanlike proactive way (rather than fully automate) (8) sense and understand intelligently (9) behave as a single intelligent hybrid being, and possibly (10) allow vocal information exchange.

Some potential applications and advantages of a naturalness approach over a usability approach have been discussed and some future challenges suggested. However what people *say* is not necessarily what they *do*, and their preferences may be different in moving rather than static cars. Therefore future work should observe and probe interactions and behaviour *in vivo* in moving cars using real controls, or realistic ‘Wizard of Oz’ prototypes [14], devising suitable simulator or road test scenarios and further adapting ethnographic techniques for the car. The constructs should then be presented back to drivers in the form of a focus group to check that their thoughts have been interpreted correctly and to seek possible alternative explanations and themes. Future work should also apply each Construct to some typical car systems, to validate with drivers that meeting each Construct does indeed correspond to increased perceived naturalness of interaction.

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