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Research Article

Psychological Road Audits: Background, Development and Initial Findings

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Abstract

Background: Road safety audits are becoming increasingly important around the world. They are often used to assess a new road before it is opened to the public, or to audit an existing highway. **Aims:** Whilst traditional road audits are of critical importance, it is hypothesized that a driver-centred approach by means of 'psychological road audits' could be beneficial for the safe road design process. The aim of this ongoing research is to develop a psychological road auditing process. **Method:** The methodology being developed currently consists of three main components. Firstly, a naturalistic driving study, in which participants drive along the road being audited. Secondly, experimenters perform an analysis of the main driving tasks: these are decomposed into sub-tasks. Finally, a driver-centred design workshop based on the tasks decomposed in component 2; this identifies risks for each sub-task by means of a participatory ergonomics process, current controls employed are noted, road design deficiencies are identified and user-centred design improvements are developed. **Results:** The project is a new Australian-Spanish-UK collaboration. For the naturalistic driving study component, initial data have been collected using a newly-opened highway in Granada, Spain. This road had a mixture of driving tasks, such as intersections and multi-lanes, plus has a comparatively high accident rate. To date, a range of experienced and novice drivers have driven the 10km route and had their verbal responses recorded. For the task analysis and driver-centred design workshop components, the driving task of 'approaching an intersection' was first decomposed into sub-tasks and then used as the subject matter for the safe design workshop. This revealed many potential road design deficiencies and suggestions for improvement. **Conclusions:** This research is still in its early stages. However, the approach used here, of providing a structured means of driver-centred safe highway design is producing potentially valuable results..

Background

Road Safety Audits and the need for an explicit driver-centred focus

Road safety audits (RSA) are growing in importance worldwide. They have been used successfully in Great Britain, Australia, and New Zealand for a number of years [1]. RSA have proved to be useful when assessing the technical aspects of the highway, such as the road surface, sight distance and junction design. Whilst traditional road audits are of critical importance, they do not have an explicit driver-centred focus [2-4]. In the ongoing work reported here, it is hypothesized that such a driver-centred approach by means of 'psychological road audits' could be a beneficial addition for the safe road design process.

Since the influential work in the United States in the 1970s and 1980s by Allen et al [5] and Alexander et al [6] regarding how road infrastructure can support driver activity through 'positive guidance', little previous work has explored this area from a human factors perspective. However, one previous study by Basacik et al [2] began this process by beginning to develop a human factor tool which could provide an objective method for assessing a road layout. Sadly, the tool by Basacik et al was never fully completed, but initial evaluations of it found that it could make valuable contributions by identifying road design deficiencies not previously noted in traditional road safety audits [2]. The current research therefore builds on their initial groundwork in this area by combining elements of naturalistic driving, task analysis and safe design.

Naturalistic Driving

Driver behaviour plays a central role in road safety risk, but it is often difficult to measure in real-world driving situations [7]. Recent developments in vehicle instrumentation techniques, as reported by, for example, Dingus et al [8] or Guo et al [9] have made it both technologically possible and economically feasible to monitor driving behaviours and vehicle data on a large scale. These data collected through advanced in-vehicle instrumentation provide an opportunity to study behaviour at an individual driver risk level [7].

Whilst the use of this approach is rapidly expanding, there are differences in the precise design of such studies; this includes the length of time of the study, whether participants

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use their own vehicles, whether routes are prescribed, and the characteristics of the participants [10-12]. Despite this, naturalistic driving can still be viewed as observation of behaviour in a more or less natural and ecologically valid setting, where participants in such studies face real driving conditions and pressures, and make real decisions that have real consequences (e.g. Hanowski et al. [11,12]).

Task Analysis

As noted by Fastenmeier and Gstalter [13], although task analysis is used a great deal in human factors, its use in driving is rare. Ideally a driving task analysis would involve a detailed study of the entire traffic system comprising the driver, the vehicle, the highway, traffic rules and regulations, the traffic which is encountered, and the natural environment in which the activity takes place.

One of the first major studies to undertake a detailed driving task analysis was McKnight and Adams [14]. They found that driving was comprised of 45 key tasks (although these tasks include maintenance tasks such as 'routine case and servicing'); driving tasks identified included lane changing, negotiating curves and planning. Since then, a few others have built on their work. For Michon [15], a task analysis is a description of facts about the driving task, the behavioural requirements and the ability requirements to successfully perform the task. Within this, he proposed a 3 level hierarchy of driving: comprising strategic, tactical and operational (control) elements [15]. Using the task analysis to uncover performance errors was of key importance to Michon [15], often these are analysed according to one of four failure modes: perception, comprehension, decision or action.

Building on such early driving task analysis work, Gstalter and Fastenmeier [16] applied a human error approach to measure car driving reliability. For this, Gstalter et al required:

- A taxonomy of driving tasks.
- A definition of correct behaviours in each of the tasks.
- A list of errors as deviations from the correct actions.
- An appropriate observation method to register these events.

The aim of Gstalter and Fastenmeier [16] was for driving task analysis to give a framework for error definition (more than the largely arbitrary task definitions they stated were often produced in previous studies). They also proposed that the overall method of error observation was useful for roadway design (e.g. for intersections) from a driver-centred perspective.

Safety in Design

'Safety in design' is an increasingly-used approach in a variety of occupational domains [17]. Also known as 'safe design', the general process seeks to eliminate health and safety hazards, or minimise potential risks, by systematically involving end-users and decision makers in the full life cycle of the designed product or system. To date, it has largely been used for product design, but it can also be used for the design of transport systems [4, 18].

The process generates design options to eliminate hazards or minimize risks to those who build the system, those who maintain it and to those who ultimately use it. Often the overall safe design process decomposes driving tasks into sub-tasks (elements), then analyses the risks and recommends countermeasures/design improvements for these smaller components in a participatory ergonomics styles setting with end-users [17].

Within a similar context, Fastenmeier and Gstalter [13] developed the 'SAFE' process (*Situative Anforderungsanalyse von Fahraufgaben*). This was a procedure for driving task analysis and driver requirement assessment. The SAFE process first divides a driving task into subtasks, these subtasks are then mapped to stretches of roadway and a time structure is determined. Then each subtask is analysed in terms of driver requirements (for perception, memory etc). Then driver errors are identified for each subtask, together with ratings of risk and complexity. Finally, it is applied to different countermeasures such as roadway design or assistive technologies [13].

For both Horberry [17] and Fastenmeier and Gstalter [13], splitting up tasks into more detailed sub-tasks allows detailed information about potential risks/problems and their possible solutions to be identified. Within the driving context, these 'safe design' solutions can be applied to aspects of highway design, driver training, or in-vehicle assistance systems [13, 17, 18]. The focus of the work reported here is upon the highway design aspect.

Method

The methodology being used consists of three main components. The three parts form an integrated approach by putting the driver, and the tasks they are required to perform, at the centre of the research at all three stages.

1. Naturalistic driving study

In this, participants drive along the road being audited; their verbal impressions and driving behaviour are recorded as they drive by means of in-cabin cameras. The participants later watch the video of it for additional responses. Our ongoing research in this area is reported below.

Highway Used

In order to carry out an initial study, it was necessary to select a road that provided a wide range of tasks for drivers to perform, such as a newly-built road that had a high accident rate (Black Spots A-44 [19-22]). For this study, a recently completed 10km section of A-44 Spanish highway near Granada was used. Figure 1 shows one of the roundabouts on the route.

Participants

A total of 16 experienced drivers (8 males and 8 females), who had more than 8 years of driving experience, and 16 novice drivers (8 males and 8 females) near to obtaining their driving licence, took part in this study. Participants were asked to perform drive normally along the test route (Figure 1). Study ethics approval was obtained from the University of Granada, Spain.

Figure 1: *Naturalistic driving study: example view from in-cabin camera*

Procedure

Following a method developed by Lansdown [23], participants were asked to drive along the road and verbalize every traffic event they thought of or considered. These verbal impressions were recorded. They were asked to say their feelings, thoughts, emotions and what they saw during the drive, especially their opinions about road design, other vehicles, and traffic signs. There were no right or wrong answers: the aim was to find out driver's first impressions about the road.

Shortly after the driving task performance, participants visualized the video recording of their task, in order to add any additional opinions about their driving experience. This followed Gstalter and Fastenmeier [16], who used video debriefs, where a participants watched a recording of their test trials, to provide supplementary information about their reasoning and underlying cognitive processes (e.g. why they did/did not do various driving actions).

2. Task Analysis

In ongoing work, the experimenters are performing an analysis of the main driving tasks along a test route. These are being decomposed into sub-tasks based on the video of the road being audited, and previous literature (e.g. previous driving task analyses [14]). To date, one driving task has been analysed: 'approaching an intersection'. This task was chosen given the relatively high accident rates at junctions and intersections compared to other driving tasks.

3. Safe Design Workshop

Finally, a workshop was conducted with the 'approaching an intersection' task analysed in component 2. It identified the risks for each sub-task by means of a participatory ergonomics process. Current controls employed were noted (e.g. road markings), potential road design deficiencies were identified and possible user-centred design improvements were proposed. This method follows a similar approach to that successfully employed by Horberry [17] for vehicle design. Again, drivers are central to the psychological road audit process: in this stage they act as workshop participants.

Participants

The participants were nine drivers who were attending a safe design workshop run by two experimenters: 2 were females and 7 males. Average age was 44; all were experienced drivers. The workshop took place in a meeting room, and the video of driving and results of the task analysis were projected onto a screen at the front of the room. It should be noted that different participants and a different test route were used from those employed in component 1, so a direct comparison of the results obtained in components 1 and 3 is not applicable.

Procedure

The safe design workshop took approximately 2 hours. The workshop procedure was comprised of four elements:

i. Context/scope definition. An overview of the process was given by the experimenters and the purpose of the workshop was clarified (in this case, to identify problems with an existing road intersection).
ii. Participants watched a video of a drive along the road being audited (filmed inside a car to approximate a driver's viewpoint).
iii. Experimenters presented their draft task analysis of 'approaching an intersection' and asked participants to confirm if it was accurate (adding/amending it as needed).
iv. Based on a draft list of highways risks and broad re-design suggestions prepared by the experimenters, the participants and experimenters then:
    - Identified risks at each of the task steps- what could go wrong.
    - Developed road re-design suggestions for these risks. The experimenters stated that these changes may include not only highway design, but the improvement of signing and marking [24], the restriction of billboards that may distract drivers [18] and the introducing of passive safety measures, such as barriers.

Figure 2 shows the overall research approach.

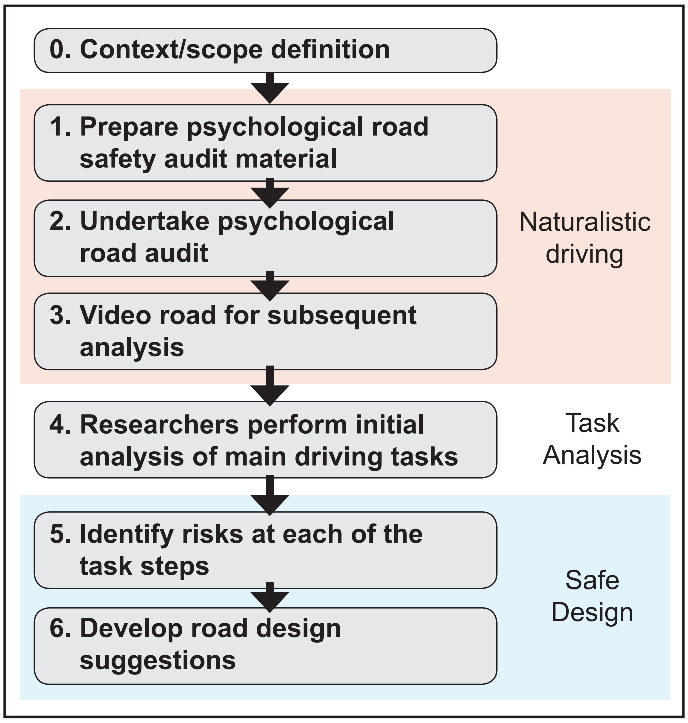

Figure 2: *Overall driver-centred research approach*

As noted above, in this research different participants and test routes were used in components 1 and 3. This was due to research constraints whereby the naturalistic driving study was funded in Spain and the safe design workshop was separately funded in Australia. For future research, and to allow a direct comparison of the results obtained in the different components, it is recommended that the same participants and test routes are employed across all three stages.

Results

This current paper is mainly about the approach being developed, so only initial results will be presented here.

1. Naturalistic driving study

In general, experienced drivers made more verbalizations than the novices (this agreed the previous findings of Lansdown [23]), but the analysis of novice drivers is not yet fully complete. Using similar analysis categories to those previously employed by Lansdown [23], Table 1 shows the number of verbalisations per category for experienced drivers.

Table 1: *Number of verbalisations recorded for experienced drivers*

Category	Men (n=8)	Women (n=8)
Vehicles (and vehicle operations)	1	1
Traffic signs	31	31
Road design	39	31
Peripheral objects on road (e.g. advertisements)	10	8
Other vehicles	12	8
Non-related to the road: Scenery and landscape	4	-

The two most popular categories emphasized by the experienced participants were road design and traffic signs. Interestingly from a safety perspective, more females than males mentioned wanting the speed limit will be higher. Both men and women claimed more traffic signs, especially those related to guidance, should be deployed. However, they considered that such signs should be more evenly distributed through the highway and should be consistent with access points and exits. Another observation made, especially by male drivers, concerned signs being obscured by the trees and other vegetation; this has clear design consequences in terms of regular highway maintenance to prevent sign obscuration. Regarding peripheral objects, both male and female drivers verbalised about advertising billboards, although women seemed to get more distracted by them (in terms of directing attention away from their primary driving task).

The two main complaints of virtually all participants were dense traffic and the design of roundabouts. Participants opined that roundabouts were very congested, with too many exits and entrances, poorly organised and difficult to navigate (this was especially true for older segments of the road, compared to newly-built stretches). Several male drivers seemed to be particularly discontented with the use of the flashing lights when entering roundabouts. All these issues have clear design consequences in terms of potential roundabout improvements. Conversely, many participants noted that exits and entrances to the highway were too narrow, which, in their opinion, provoked traffic jams.

Finally, most participants complained that the other vehicles on the route did not properly consider traffic signs or other drivers. Women complained more than men about other drivers' behaviour and driving styles.

2. Task Analysis

The seven subtasks identified for the overall task of 'approaching an intersection' were:

i. Driver identifies that an intersection is being approached.
ii. Driver decelerates.
iii. Enters the correct lane.
iv. Signals, if needed.
v. Observes traffic controls (lights and signs).
vi. Observes other traffic.
vii. Stops if traffic light on red.

The accuracy of this task analysis was subsequently verified in component 3 by asking the participants if the sub-tasks were correct. These seven steps corresponded well to those previously identified by Mcknight and Adams [14]. The two additional steps agreed in this workshop were at the beginning and end of the task ('Driver identifies that an intersection is being approached' and 'Stops if traffic light on red'). These may reflect where the two studies considered the intersection approaching task to begin and end.

3. Safe Design Workshop

Table 2 (over page) shows the outcomes of the safe design workshop. Prior to the workshop, the experimenters produced a draft list of highways risks and broad re-design suggestions. These were reviewed, amended and expanded in the workshop itself. As can be seen, the re-design suggestions offered by the drivers include not only highway design changes (such as improved lane marking), but also modifications to the area around the highway (such as advertising billboard restrictions).

Discussion and Conclusions

As can be seen in this ongoing research, results are beginning to emerge. As such, this paper focuses primarily on the background and methods being developed and secondarily on the initial results obtained. But our approach combines many influential processes of key importance to contemporary human factors, such as task analysis, safe design and naturalistic driving. As seen in the workshop of the 'approaching an intersection task', this user-centred approach is beginning to produce a rich catalogue of potential highway issues. As Basacik et al [2] previously found, such driver-centred processes can make valuable additional contributions to road safety audits; however, the formal evaluation of our approach and a direct comparison of the results obtained from naturalistic driving component and the driver-centred safe design workshop component will be the subject of future research.

Table 2: *Safe design workshop outcomes*

Task	Sub-tasks	Possible risks or design deficiencies for each sub-task	Re-design suggestions
1. Approaching an intersection	*1.1 Driver identifies that an intersection is being approached*	- Driver not identifying upcoming intersection at the appropriate time - Inappropriate speed limit	- Better road markings and signage to help identify upcoming intersection - If possible, redesign and simplify junction so traffic turning right uses an overpass rather than crossing over oncoming lane
	1.2 Driver decelerates - not too early - but in sufficient time to stop	- Going downhill to junction: hard to slow down - Driver does not correctly identify point to begin slowing down - Driver decelerates too early (danger to other traffic) - Driver decelerates too late	- Do not put complex junctions on hills - Minimum speed signs - Additional signage about intersection - Warning road markings (e.g. lines across road) - Check accuracy of GPS/satellite navigation systems
	1.3 Enters the correct lane - in sufficient time	- Possible distraction from large billboard on left - Unsure about lane choice and direction	- No billboards at junctions - Better advanced direction signs - Lower speed limit - Provide means for error recovery (e.g. driver can return to 'correct' lane
	1.4 Signals, if needed	- Not signalling - Wrong signalling (e.g. indicating left and going right)	- Arrows on road to reduce need for signalling - Better lane marking
	1.5 Observes traffic controls (lights and signs) - prepares to stop if red/amber - continues observing if green	- Too many signs and other street furniture (driver overload) - Signs/lights obscured by traffic or vegetation - Signs/lights not readable: e.g. worn, dirty or in the sun - Mismatch of information (e.g. lights show green for straight on, but red for turning); causing confusion	- Reduce unnecessary clutter - Situate signs high, and regularly cut back vegetation - Regular maintenance of signs/lights - Check if confusions exists by asking drivers who have previously driven through the area
	1.6 Observes other traffic - oncoming - in front, at sides or behind	- Distracted by oncoming traffic - Distracted by traffic around	- Screen oncoming traffic to make it not visible to driver - Use clear lane markings
	1.7 Stop if traffic light on red	- Not stopping if light on red - Stopping too late if light on red	- Use red light cameras - Review speed of change of traffic lights - 'Advanced' traffic lights showing status of actual lights ahead

As the three stage methodology involves a naturalistic driving component, the approach is currently most suitable for auditing newly-opened roads or existing accident black spots rather than reviewing the conceptual design of a planned highway. However, with some modification, the task analysis and safe design workshop phases could be employed to audit the early design stages of a highway based on the driving tasks likely to take place. Adding a structured, driver-centred, task-based approach to highway design and auditing is our ultimate goal to help improve road safety across the full lifecycle of a highway.

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