Evaluating Automotive Sound Quality: The Disconnect Between Market Research and Structured Evaluations

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Declaration

I confirm that the work in this thesis is my own unless stated. I also confirm that this thesis has not been submitted for a degree at another university.

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Abstract

Understanding how customers evaluate product attributes is a vital part of New Product Development (NPD). Vehicles in particular have many attributes which can contribute to a positive perception of the vehicle and its brand. The attribute of vehicle Sound Quality (SQ) is particularly important and automotive Original Equipment Manufacturers (OEMs) employ a variety of techniques to collect customers' subjective evaluations of SQ in NPD, both during product development and after purchase. There are two main techniques for collecting customers' subjective evaluations: structured evaluations and market research.

Structured evaluations are conducted in controlled experimental conditions. This allows engineers to set targets for the design of automotive SQ for new vehicles. Market research on the other hand, is carried out in an unstructured manner, and does not inform engineers of the underlying criteria vehicle owners use to evaluate vehicle SQ. Nevertheless, market research can be influential for attracting new customers, therefore it is important for OEMs to achieve favourable ratings. However, it is currently not understood how market research methods compare to structured evaluations for automotive SQ, which leads to low confidence in interpreting customer data.

A preliminary study examined customer data issues facing an automotive OEM and confirmed the need to further understand vehicle owners' decision-making and behaviour in evaluations. Therefore, this research aims to answer the question, how do the decision-making criteria used by assessors compare between market research techniques and structured evaluations?

By adopting a psychological approach, a second study was conducted to examine customers' decision-making in automotive SQ structured evaluations and in a market research survey. Verbal Protocols were used as the primary data collection method. The second study identified four decision-making criteria which were used by assessors when evaluating automotive SQ in a listening room structured evaluation and a market research survey. The criteria were classified into 1) behavioural scenarios, 2) attribute criteria, 3) comparisons and 4) expectations. An Odds Ratio showed vehicle owners in a market research setting were twice as likely to use behavioural scenarios in comparison to a structured evaluation. Vehicle owners in the structured evaluation, made more comparisons to specific stimuli that were experienced and focussed on the sound stimulus presented as opposed to behavioural scenarios.

A third study investigated customer decision-making in an interactive vehicle simulator, which was most representative of real-life driving. Behavioural scenarios were used by vehicle owners, in a similar frequency as those in a market research survey, which validates the usage of simulators in NPD. Simulators are therefore important tools to help experts anticipate how vehicles will be evaluated in market research. This thesis provides experts with the knowledge of how vehicle owners evaluate their vehicles in market research surveys and as a result it can inform the design of structured evaluations, which occur earlier in NPD, before the post-purchase market research has taken place.

This thesis demonstrates a behavioural disconnect between structured evaluations and market research techniques. It provides knowledge on the decision-making criteria which vehicle owners use to evaluate vehicle SQ in structured evaluations and market research. This knowledge can ultimately give engineers more confidence in interpreting customer data and the ability to better anticipate customer responses, through a better understanding of how vehicle owners evaluate vehicle SQ, rather than just knowing their preferences. It also validates the use of vehicle simulators in NPD.

Abbreviations

3-D – 3 Dimensional

AIS – Active Information Search

ANOVA – Analysis of Variance

CQI – Continuous Quality Insights

CRM – Customer Relationship Management

dBA – Decibels Adjusted

DF – Degrees of Freedom

GSR – Galvanic Skin Response

IQS – Initial Quality Survey

JDP – J. D. Power

Km/h – Kilometres per hour

LR – Listening Room

MR – Market Research

NCBS – New Car Buyer Survey

NPD – New Product Development

NVES – New Vehicle Experience Survey

NVH – Noise, Vibration and Harshness

OEM – Original Equipment Manufacturer

OR – Odds Ratio

PC – Personal Computer

R – Respondent

RPM – Revolutions per minute

S – Seconds

SIM – Simulator

SQ – Sound Quality

TGW – Things Gone Wrong

TIV – Total Industry Volume

TLP – Thought Listing Protocol

TTM – Time To Market

U.S – United States

UK – United Kingdom

VAG – Vehicle Assessments Group

VDS – Vehicle Dependability Survey

WOT – Wide Open Throttle

Chapter 1
Introduction

1. Introduction

This thesis presents the research carried out in order to understand the decision-making criteria used by assessors in vehicle attribute evaluations. This chapter outlines the background to this research and presents the research questions, objectives and structure of this thesis.

1.1. Research Background

Automotive Original Equipment Manufacturers (OEMs) need to manufacture vehicles that appeal to a range of customer needs while also overcoming engineering challenges in New Product Development (NPD) (Weber, 2009). Additional factors force OEMs to introduce vehicles to market at the correct time and to ensure that the designed attributes which contribute to the experience of driving the vehicle meet customer needs (Williams et al., 2005; Sörenson, 2006; Kossiakoff et al., 2011). Vehicles include many attributes, (e.g., ride quality, sound quality, and comfort) which elicit subjective responses from drivers and create perceptions of the vehicle (Braess and Seiffert, 2005). Understanding customer's evaluations of vehicle attributes in NPD could increase the likelihood that the vehicle will generate revenue for the OEM, as the vehicle will be more likely to meet the customers' requirements in the marketplace (Buchanan and Gillies, 1990; Fornell, 1992; Vavra, 2002). A range of customer research methods can be used in automotive NPD, however not all share the same degrees of reliability and validity in capturing customer subjective responses. Therefore, it is important that the methods which are used for collecting customer perceptions are further understood in order to provide accurate customer evaluations to be used in vehicle attribute development.

1.1.1. Customer Research Approaches

Customer research for vehicle attributes can be conducted either through structured evaluations or market research. Although both these approaches provide automotive NPD with customer responses to configure vehicle attributes, there are methodological differences which create advantages and disadvantages, which will be further outlined in Chapter 2. The integration of market research and structured evaluations data could be complimentary (Beers, 2008) and

benefit the automotive OEM with an improved understanding of customers within NPD, but these approaches remains to be fully understood. A comparison of customer research approaches only remain hypothesised. Providing the opportunity to compare the customer research approaches in terms of how assessors evaluate vehicle attributes in a series of empirical evaluations assessing decision-making criteria used by assessors, may further extend the current state of knowledge.

Structured Evaluations

Structured evaluations are carried out in controlled laboratory settings e.g., Listening Room and Simulator-based evaluations, which are controlled to ensure that the vehicle attributes under evaluation are presented to assessors in a repeatable manner and with minimal external influences (Böckle, 1996; Hanington and Martin, 2012). Structured evaluations consist of designed questions and data capture techniques to help ensure that the responses from assessors are easily interpreted in NPD to set engineering targets for vehicle attributes.

Market Research

Alternatively, customer's opinions, preferences and subjective responses can be collected through market research techniques. Automotive satisfaction surveys are one of the ways new and existing customers can relay their responses to automotive OEMs. They can be carried out by the OEM or through market research agencies such as J.D. Power (Balasubramanian et al., 2005). The published results from market research studies could be influential for attracting customers towards a particular vehicle (Ludvigsen, 1996). Market research can also be used to benchmark attributes with competitors vehicles, which allows attribute development year-on-year. This emphasises the need for OEMs to achieve favourable results. However, market research techniques are carried out in environments with fewer control measures than structured evaluations, e.g., no stimulus presentation and no control over external influences. This can add to the difficulty of interpreting results which are collected in the absence of automotive product designers and engineers, resulting in lower confidence placed in ratings.

1.2. Research Need

Due to the subjective experiences created from vehicles, it is important to understand how customers respond to principal vehicle attributes, so that engineers can better address customer needs. In order for OEMs to improve their understanding of customer needs from the available data sources, structured evaluations need to provide an in-depth understanding of 'how' customers think about vehicles. Designers and engineers can use market research data in the planning and definition stages in NPD to deepen their understanding of how the final product will be evaluated. However, market research does not share the same level of control as structured evaluations, e.g., set in a laboratory, and is only captured once the customer has purchased the vehicle, long after the NPD process leaving engineers to use data which could be less relevant. This potentially creates a number of disconnects between the two approaches for collecting customer research.

One challenge is that the quantitative data currently available from each approach only provides engineers in NPD with measurement scores of the attribute and not 'how' people evaluated the vehicle attribute, which can be important for understanding how the approaches compare with each other. Therefore, evaluating the numerical data available from the customer research methods could be inadequate to provide the understanding needed to improve data interpretation from customer research.

One of the ways to examine the disconnects is to understand how customers evaluate vehicle attributes in structured evaluations and market research from a psychological perspective by examining the customers' decision-making criteria. This research raises the question of how does the evaluative decision-making criteria customers use in a market research compare to those used in a structured evaluation? The second question raised is, whether the decision-making criteria customers use to evaluate vehicle attributes in a market research survey can indeed be considered earlier in the NPD process when the vehicle is being developed, i.e., with structured evaluations?

In order for structured evaluations in NPD to anticipate how customers will evaluate vehicle attributes after they have purchased the vehicle, it is vital to understand how assessors evaluate and make decisions in both structured evaluations and market research approaches. Incorporating customer perceptions and decision-making criteria from a post-purchase evaluation earlier into NPD could further guide the OEM to develop vehicle attributes which positively add to the experience of driving and owning the vehicle. This research could further help the OEM to consider the important criteria which vehicle owners use to evaluate vehicle attributes.

To date, there is no published literature which compares how assessors evaluate vehicle attributes in automotive market research surveys and structured evaluations. A preliminary study with an automotive OEM was conducted to better understand issues when integrating customer research data into NPD. The study further confirmed the need to better understand 'how' individuals evaluate vehicle attributes by focusing on their decision-making and customer behaviour. This emphasised the value and motivation for conducting this research.

In order to understand the influences of customer research approaches on assessors, Verbal Protocol techniques were identified from the literature (Ericsson and Simon, 1993; Schulte-Mecklenbeck et al., 2011) as being a suitable tool for revealing the thought processes that customers use in evaluations (Chapter 3). The underlying influences in approaches could be observed by investigating customers' decision-making processes which are verbalised during vehicle evaluations. The new insights could improve the interpretation of customer data in NPD, allowing OEM experts to focus on the decision-making influences which occur in market research earlier than previously possible.

1.3. Research Approach

The disciplines involved in this thesis include Psychology, Engineering, and Human Factors. The subject area of Human Factors focuses on understanding the usage of products (Stanton, 1998; Nemeth, 2004), where Psychology can be used to identify the reasons behind human

behaviour (Carlson et al., 2004). These disciplines overlap with Engineering, to include vehicle manufacturing and are used to develop an understanding in NPD (Fig 1.1).

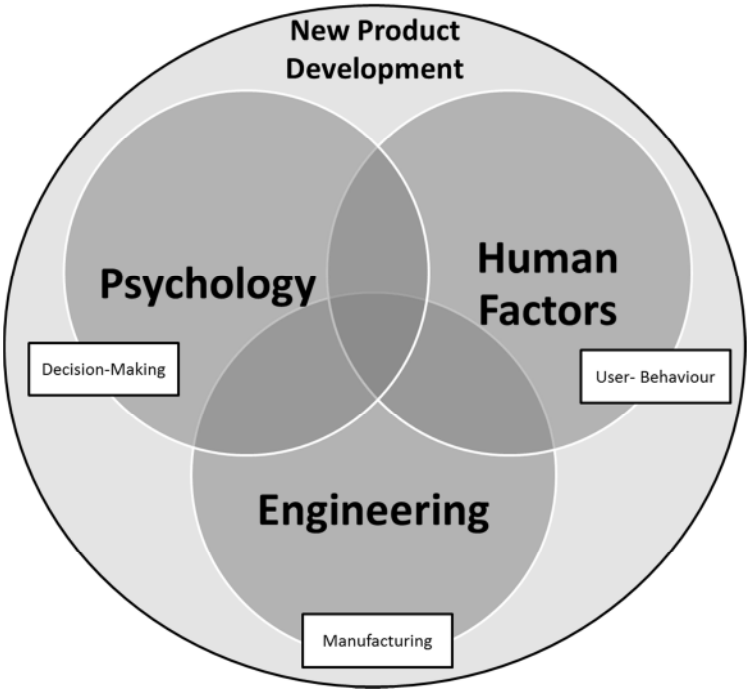


Figure 1.1: Multi-disciplinary overlap of the subject areas in this thesis

While this thesis necessarily contains multi-disciplinary elements, a perspective from the Psychology subject-domain was adopted and directed the research towards understanding the decision-making influences on assessors taking part in the evaluations. The adopted approach provided the flexibility to assess two different evaluation techniques while also maintaining experimental control which was needed during the empirical research. This thesis presents a novel way to examine a research problem which would otherwise be investigated from an Engineering perspective.

Focus on Automotive Sound Quality

Automotive Sound Quality (SQ) was selected as the specific focus of this research, as it provided the opportunity to assess the influences of both structured evaluations and market research approaches. Automotive SQ is a principal vehicle attribute which lets drivers know how the vehicle performs and how 'well-built' the vehicle is, due to its very subjective nature. Automotive SQ is also suggested to have a vast impact on the level of customer satisfaction drivers may feel about the vehicle (Dunne, 2003). Therefore, investigating automotive SQ adds

potential to understand a real world problem within the automotive industry and creates the opportunity to generate relevant knowledge about how assessors make subjective assessments in structured evaluations and market research.

1.4. Research Questions and Objectives

This research aims to understand how automotive customers evaluate vehicle attributes in structured evaluations and market research, which can be achieved through the following questions and objectives.

Research Question 1) What are the strengths/weaknesses of the current usage of customer research data within automotive NPD and what are the current sources of data used?

- **Objective 1) -** To identify knowledge which can further the current understanding of customers from existing sources of customer research data used within the automotive industry.

Research Question 2) How do the decision-making criteria used by assessors compare between market research techniques and structured evaluations?

- **Objective 2 A) -** To understand how assessors evaluate vehicle sound in structured evaluations and market research, through the use of Cognitive Interviews.
- **Objective 2 B) -** To compare structured evaluations with market research in terms of decision-making criteria.

Answering the questions and achieving the objectives contributes towards creating new knowledge by understanding the information used by assessors in each evaluation approach, which is otherwise inaccessible to those working within automotive NPD. Furthermore, this research creates new knowledge by providing designers and engineers with a better understanding of the influences of the evaluation methods on customers, when using customer data in NPD.

1.5. Scope

Vehicles consist of many attributes however, to allow an in-depth investigation this research will focus on a single attribute – vehicle SQ. The approaches for collecting customer research in this thesis can also be used in practice to assess a variety of automotive attributes which contribute towards the experience of driving a vehicle. Therefore, the approach to understanding decision-making information which is elicited by methods in this research, may be generalised to the wider area of other vehicle attributes, (subject to further validation).

1.6. Thesis Outline

The research will be presented in the following chapters:

Chapter 2: Customer Research in Automotive New Product Development – A review of customer research within NPD which examines the data collection approaches, and identifies challenges facing automotive OEMs.

Chapter 3: A Review of Decision-Making Methods to Understand Customer Evaluations – A review of methods which can capture the decision-making criteria assessors used in evaluations.

Chapter 4: Understanding Subjective Responses in Automotive Sound Evaluations – Previous work on the subjective evaluations in automotive SQ as a specific attribute is reviewed and critiqued.

Chapter 5: Research Methodology – The mixed-method approach and research design adopted for the research is established and justified.

Chapter 6: A Study to Understand the Usage of Customer Research Data within an Automotive Manufacturer – A preliminary study used an Affinity Diagramming method with an automotive OEM to identify the sources of customer data, and evaluate their usage in automotive NPD.

Chapter 7: A Study Using Verbal Protocols in a Market Research Survey and a Listening Room – This study examines the decision-making criteria assessors use to evaluate vehicle sound in a market research survey and in a listening room structured evaluation with a Verbal Protocol technique.

Chapter 8: A Study Using Verbal Protocols in an Interactive Vehicle Simulator – To further examine vehicle owners' decisions in a method representative of driving. This study investigated the role of behaviour in SQ evaluations using an interactive vehicle simulator.

Chapter 9: General Discussion – This chapter makes a comparison of the decision-making criteria identified in this research. Potential explanations of the differences are examined along with how the results can be generalised and contribute to knowledge. Suggestions for further research are made.

Chapter 10: Conclusions – This chapter summarises the findings and key learning from this research.

Chapter 2
Customer Research in Automotive New Product Development

2. Customer Research in Automotive New Product Development

2.1. Introduction

This chapter presents a literature review of the involvement of customers in NPD specific to the automotive industry. This review aims to identify potential challenges facing the automotive industry which will be used to establish the context of this thesis.

2.2. New Product Development for Vehicles

Krishnan and Ulrich (2001) define NPD as a, "*Transformation of a market opportunity and a set of assumptions about product technology into a product available for sale"*. For the automotive industry, NPD includes designing, manufacturing and marketing processes of the vehicle (Sanongpong, 2009).

As vehicle attributes can define a vehicle's driving character (Braess and Seiffert, 2005), the involvement of customer research is important to engineer attributes so that they meet customer needs. Especially as approximately 20,000 individual components are needed to manufacture a vehicle (Sörenson, 2006). It is important to understand how customers react to the experiences created by the vehicle, and for OEMs to try to ensure that the vehicles manufactured achieve the targets set, to create the intended driving experience for customers.

By trying to ensure that the vehicle will deliver the defined driving experience and intended perception for customers, OEMs can employ the use of customer research techniques. This can help to ensure that the vehicle can generate sales and also reinforce the defined driving characteristics outlined by the OEM and experts, in order to meet customer needs (Liker et al., 1996). Before the role of customer research can be further evaluated, this review will first establish the stages in NPD and outline an approach adopted by OEMs to manufacture a vehicle.

2.2.1. Automotive New Product Development

The development processes to manufacture a vehicle follows five stages outlined by Sanongpong (2009):

1) **Plan and Define Programme** – This involves creation of a design specification which include customer requirements and engineering criteria (Otto and Wood, 2000). This stage can clarify the segment that the vehicle will enter and allows designers to consider the size/seating arrangements of the vehicle (Braess and Seiffert, 2005).
2) **Product Design and Development** - Once the product is defined, steps are taken to design the character of the vehicle, e.g., sporty/dynamic.
3) **Process Design and Development** – Developing a vehicle can span more than 18 months. It is important to determine if the product design can be manufactured. The process required in NPD to manufacture the vehicle, also needs to be designed to ensure that the vehicle is manufactured with the necessary resources available.
4) **Product and Process validation** – The verification stages aim to ensure that the customer and engineering targets are met. In later stages of NPD the vehicle is no longer in conceptual format and can be physically tested through the use of prototypes. This can allow the vehicle dynamics to be tested, which include vehicle SQ and additional attributes, e.g., ride quality and comfort. This is to ensure that they perform to the customer's requirements and to determine if the brand values are achieved.
5) **Launch -** Product launch indicates that the vehicle can be manufactured.

2.2.2. Levels of Vehicle Design

One of the first tasks in the planning and defining stages of vehicle NPD is to define the level of design. There are four levels of vehicle design found from the available literature (Braess and Seiffert, 2005; Morgan and Liker, 2006; Weber, 2009):

- **Complete Redesign** – The intended vehicle is designed from new, including components and vehicle architectures. A redesign coincides with the expected life of a car, which is seven years. It is suggested by Weber (2009) that this level of design requires the most resources in NPD. This level of design can require an in-depth understanding of customers to allow designers and engineers to appreciate the needs of the target market
- **Derivative Design** - This level of vehicle design utilises existing vehicle architectures and internal components. By sharing internal components and platforms, OEMs can save on production costs. Customers may perceive this design as a new vehicle being unaware of the similarities the vehicles share with a base model. Options during the design become confined due to the limitations of the base vehicle model.
- **Variant Design** – This design allows the OEM to create a range of body shapes for the vehicle, e.g., coupes, estates or convertibles. The same architecture and major components of the base vehicle are shared. Variant designs are often included when OEMs introduce newly designed vehicles.
- **Model Updates (Facelift)** – These include minor design changes and are usually introduced after the first half of the vehicles life cycle, at around 3.5 years. Weber (2009) adds that the aim of facelifts is to create an improved perception of the vehicle, with the lowest amount of development costs and therefore may rely less on customer data. Although facelift designs are not relatively involved in the NPD, it is worth mentioning this level of design, to gain an in-depth perception of the design processes.

2.2.3. Systems Engineering Approach to Automotive Product Development

Systems Engineering can be used to strategize NPD of vehicles. Systems Engineering is defined as, a formal process for the development of a complex system, which is driven by a set of established requirements (Austin, 2007). Kossiakoff et al. (2011) add, "*Systems Engineering guides the engineering of complex systems"*, which are characteristic of the following:

- **Engineered products -** which satisfy a specified need, e.g., a vehicle is made to satisfy customer needs.
- **Systems of diverse components -** These have an intricate relationship between the systems and components which can be complex, e.g., vehicle components need to work harmoniously with other systems, sub-systems of components, which could contribute towards the vehicle attributes.
- **Areas using advanced technology –** Which include development risk and are costly, e.g., technologies incorporated into new vehicles.

Target-setting, Evaluations and Verification

Another benefit for adopting a Systems Engineering approach for automotive NPD is the validation and verification stages which are involved which help to ensure that the systems, sub-systems and components in the vehicle achieve their functions and perform as intended (Pineda and Kilicay-Ergin, 2011). This can assist the OEM to achieve the desired outcomes (Otto and Wood, 2001) and try to ensure customer needs are met.

A V-Diagram (Fig. 2.1) is often used to visualise this process, as it provides checkpoints during the development of each vehicle component, subsystem and system and attribute (Kossiakoff et al., 2011). The V-Diagram helps those in NPD to ensure that the vehicle follows a sequence of processes which are designed to ensure that the correct resources are present in NPD. It also helps to ensure that the vehicle achieves the targets set out and is verified before progressing throughout the development stages.

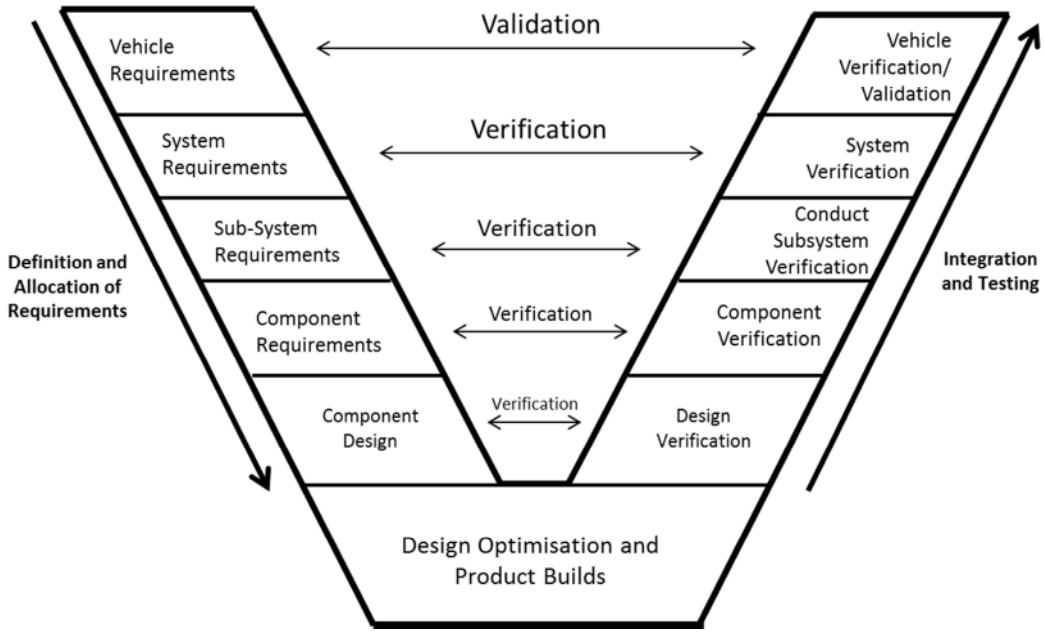


Figure 2.1: A V-Diagram used for vehicle development (Adapted from Austin, 2007)

Within the verification and validation processes, OEMs can rely on benchmarking to help ensure that the vehicle attribute in development, achieves the targets set in the product definition stages. Spall and Ahn (2000) highlight how benchmarking can create opportunities for the engineering team to adopt similar solutions as competitors and the potential to exceed them.

2.2.4. Challenges facing Automotive Product Development

This section identifies potential challenges facing automotive product development. The available literature of automotive NPD reviewed so far has shown that achieving customer needs is one of the main focuses of the vehicles production stages and vehicle design levels. This section will finalise the context of this research before evaluating the approaches available to collect customer research by covering potential challenges facing the automotive industry, which could be considered as the rationale for using customer research in NPD.

Time to market

Automotive OEMs need to consider standards set in the industry in terms of reliability, safety and quality. This can result in longer development times often spanning between 24 and 36 months, however OEMs are aiming to reduce this (Spall and Ahn, 2000). It is important that the vehicle is released into to the market at the intended time. It is suggested that a delay of 6 months could result in 25% opportunity loss in profits (Smith and Reinersten, 1991).

Cost

Developing a passenger vehicle costs in the region of £1 billion (Sources: BMW Annual Report 2011; Jaguar and Land Rover - Directors Report, 2011). This high level of investment further justifies the need to make sure that the vehicle meets customer needs, before the vehicle is launched. This could help to generate revenue for OEM, once the vehicle is on sale.

Competition

Due to market saturation, Ludvigsen (1996) describes the automotive market as a '*buyer's market*', which forces the emphasis of product development to be focussed on customers. The automotive market is saturated with OEMs. The UK market had a turnover of £49 billion in 2010 and is home to 7 volume OEMs and has over 10 specialist OEMs (Source: Society for Motor Manufacturers and Traders – Motor Industry Facts 2012). Automotive OEMs face intense competition across a range vehicle segments and classes, e.g., luxury, premium, small/compact and sports etc. Automotive OEMs therefore seek ways to draw customers away from competitors. This can be encouraged in NPD through a process known as benchmarking which allows an OEM to try and achieve competencies where competitor products may fail. At the same time, OEMs can refine their corporate identities and brands, which can be developed to be coveted by customers (Balmer and Gray, 2003). This can improve the desirability for certain brands to attract customers (Johansson-Stenman and Martinsson, 2006).

Technological and Material Advancements and Complexity

Technological advancements and lighter materials in NPD, e.g., aluminium and carbon fibre, could allow vehicles to be designed without as many limitations which have faced OEMs in the past. However, it raises the question of 'what' it is customers require from modern vehicles. In the advent of mass customisation which faces automotive OEMs, further adds to the complexity in NPD and can escalate costs (Alford et al., 2000).

Involving Customers in New Product Development

In order for the vehicle to be developed and purchased by customers, knowledge of the intended customer is essential (Kärkkäinen et al., 2000). To ensure that the intended driving experiences

are relayed to customers, the vehicle attribute needs to be evaluated in NPD. If OEMs fail to deliver an acceptable product, it is suggested that they will lose their customers (Kotler et al., 1996). This creates a challenge for automotive OEMs to incorporate the correct customer feedback within NPD.

As automotive OEMs may purchase customer research and are focussed on the attribute scores, they may not always observe the evaluation process carried out by customers and therefore fail to observe the evaluation criteria for evaluating vehicle attributes. The estimated perception of customers by experts can be a reason why some products fail due to being unrealistic (Ludvigsen, 1996; Vavra, 2002). Examining existing research which captures customer data for NPD, can help determine the existing state of knowledge and the advantages/disadvantages of the methods used to involve customers into NPD.

Subjectivity of Customer Data

One of the additional challenges with involving customer data into NPD is that vehicle attributes can elicit a range of subjective responses, which makes the interpretation of customer data very difficult. Interpreting customer data also raises a challenge in automotive NPD. For example, Mittal et al. (2001) highlight how firms may interpret customer data by identifying attributes that make up the product, and then aim to gauge how each attribute performs and influences the overall level of satisfaction for customers. Although products can be engineered with a focus on customer data, a difference in the interpretation of data between experts and non-experts can occur (Vavra, 2002). This can lead to different opinions between customers and employees. Research to understand how customers evaluate products from customer research methods may help designers and engineers improve their understanding of customers. Veryzer (1998) identifies the benefits of informing designers and engineers with customer knowledge earlier in NPD and recommends industrial designers and engineers to be part of the market assessment clinics, as they may have different perceptions of the product to the customer.

Specific recommendations to help improve automotive OEMs interpretations of customer data from product perception studies were not identified from the available literature. Thomke and

Hippel (2002) highlight how fully understanding customers is a challenging and costly task. The lack of literature indicates a potential research opportunity which can help to direct the focus of this research to understand the approaches used for collecting customer research in NPD. This could identify the issues regarding data collection and interpretation. The current literature review can help determine the current state of knowledge towards understanding subjectivity of responses from customers. Examining the methods available could further identify potential areas which can be researched further in this thesis.

2.3. Customer Research

Due to the broad nature of customer research and the lack of a definition, this thesis defines customer research as a collective term for initiatives carried out to identify information or measurements of individuals belonging to a target market, who will potentially purchase the product. The advantages of carrying out customer research include allowing an improvement in product quality (Perkins, 1993) and help to ensure successful products are designed, which can then improve the profitability of a company (Cooper, 1994; Matzler et al., 2005; Kleef et al., 2005). Additionally, through customer research OEMs are able to understand how the vehicle is performing in the marketplace (Yadav and Goel, 2008) which allows them to become customer-focussed. This can further encourage product success (Cooper, 1994; Song and Parry, 1997a)

Automotive OEMs have to ensure that they are up to date with customer needs, which can help anticipate customer choices, particularly in the earlier stages of NPD (Coen et al., 2005). Jin et al. (2009) report that product performance alone was sufficient to entice customers towards purchasing a product in the past but with customer expectations becoming diverse, automotive OEMs need to develop vehicles which can satisfy customer requirements in order to remain successful. Customer research can be used to help OEMs reduce the uncertainties of designers and engineers decisions involved in NPD by understanding what potential customers find acceptable for vehicle attributes.

Kärkkäinen et al. (2001) further emphasise the need to involve customers throughout the entire phases of NPD to continually ensure that the product meets any changes in customer needs. You

et al. (2006) propose that as the performance levels of the vehicle become satisfactory, other attributes of the vehicle can become more important amongst customers such as the driving comfort and features to assist driving. This has led OEMs to identify potential opportunities from vehicles to deliver improved luxury and further ways to attract customers in order to be successful (Dahl et al., 1999; You et al., 2006).

One traditional approach is based on introducing novel technologies in order to keep customers attracted to the vehicle and increase satisfaction (Kano, 1974). However, this may not always produce the intended effect. Auer (2004) highlights how a premium automotive OEM announced the removal of several hundred features from a luxury vehicle, because the drivers did not know how to use them. This demonstrates the importance for understanding customer needs in NPD.

2.3.1. Measurements of Customer Research

Customer research can be further categorised into (i) assessment based or (ii) identification purposes (Annett, 2002). Identification methods aim to discover any potential issues from customers, whereas assessment methods aim to evaluate and assess existing product attributes. There are many customer characteristics, which can be measured for vehicle attributes. The available literature for understanding customer measurements in product development can be categorised into the following measures:

Customer Satisfaction

Oliver (1996) defines satisfaction as, "*…a judgment that a product itself provided a pleasurable level of consumption-related fulfilment, including levels of under- or over fulfilment.*" Customer Satisfaction is seen as an indicator for product or service performance which could encourage customers to repeat purchases and is also seen as an indicator of loyalty between the brand and customers. Customer satisfaction levels therefore could have a financial impact on the profitability of an organisation (Kotler, 1991; Sharma et al., 1999; He et al., 2007).

Customer Preferences

Many products and services offer a variety of combinations or customisations. Understanding Customer Preferences can help identify popular configurations for customisable products (Tseng and Du, 1998). In order to understand vehicle choices and preferences, automotive OEMs can run a number of techniques and tools to understand the popular product configurations. Examples include online vehicle configurations based tools to allow OEMs to understand customer configurations and choices. Conjoint Analysis can also be used (Green and Srinivasan, 1990).

Customer Behaviour

Understanding how products are used by customers could be advantageous for designers and engineers. Using a vehicle requires a significant amount of interaction, where drivers are constantly being presented with a variety of different sensory information, be it visual, touch, auditory or even through smells. Understanding how products are used can be carried out in Concept Testing in NPD (Cooper and Kleinschmidt, 1986). This can help ensure that the product relays the important product characteristics to customers. Specifically to the automotive context of this review, driver behaviour could identify problems or issues which face certain features of the planned vehicle. Assessing driving behaviour can be carried out using interactive vehicle simulators which will be discussed in the next section. Approaches for collecting customer research will be established next.

2.4. Approaches for Collecting Customer Research

Customer research methods used within the automotive industry can be broadly categorised as either structured evaluations or market research. As this thesis focussed on vehicle SQ specific evaluation methods will be reviewed in Chapter 4, but are broadly outlined next.

2.4.1. Structured Evaluations

Evaluations are defined as attempts to gauge human expectations against a designed artefact (Hanington and Martin, 2012). A structured evaluation however, includes a systematic component in the appraisal. This may be in the form of set questions, prompts, set-tasks and

defined metrics (Böckle et al., 1996). Structured evaluations allow subjective responses to be captured from assessors for product attributes in controlled laboratory conditions. Specialised customer clinics can be used to help determine how customers will evaluate a vehicle, and are also regarded as structured evaluations due to the experimental control required in the study (Urban and Hauser, 1990). The advantages of conducting structured evaluations include:

- The prevention of external influences on the stimulus under evaluation.
- Structured evaluations provide a set-layout for evaluating products and their attributes which can introduce rigour and allow repeatability into a subjective evaluation.

Vehicle Attribute Structured Evaluations

Based on the principles of structured evaluations, vehicle attribute structured evaluations focus on a single vehicle attribute and are conducted in designed laboratory conditions. This helps to ensure that the attributes under evaluation are not influenced by external influences, and allow the environment to be controlled when the stimulus is presented. These evaluations are designed to capture the subjective responses from assessors, which in turn allow engineers to set targets in NPD.

Interactive Vehicle Simulators

Vehicle simulators within the automotive industry can also be used as structured evaluations which allow customers to drive a vehicle in a virtual environment where the driver is subjected to the same sensations that would otherwise be experienced in a real vehicle. The added benefit comes through the use of the software which can define the driving conditions such as road surfaces and the virtual environment, e.g., traffic. Influences such as the weather can also be controlled. Simulators can allow automotive experts to programme various dynamics and vehicle characteristics for the structured evaluation and can observe assessors behavioural inputs and capture the subjective responses for a range of vehicle attributes. There are different types of simulators which vary the level of participant immersion e.g., desk-top simulators to full sized vehicle simulators.

2.4.2. Market Research

Market research techniques can provide an alternative approach to structured evaluations for customer research which also aim to assess the needs and wants of customers and can be used to collect information for the next product in the design process (Krishnan and Ulrich, 2001). Market research data is highly anticipated by automotive OEMs, as they are keen to determine how their vehicles perform in the marketplace. Zikmund (1997) describes how market research can be used to encourage effective decision-making within OEM management, which can help convert the intuitive feelings amongst management, towards making an objective decision in NPD. This is important, as the management of NPD make the important design and engineering decisions on behalf of customers, with the aim to satisfy customer needs (Ludvigsen, 1996). As a result market research is suggested to be an influential tool for automotive OEMs towards attracting new customers.

Customer Satisfaction measurements supplied from market research sources provide potential buyers with information of a vehicle and their potential competitors. Market research data can also contribute towards enhancing the desirability of the brand OEMs can create (Balmer and Gray, 2003). Therefore, automotive OEMs benefit from achieving favourable statistics. In order to measure Customer Satisfaction, there are a number of methods to identify how customers perceive products.

Automotive Satisfaction Surveys

Surveys are one of the methods that the market research industry uses to capture Customer Satisfaction. J. D. Power and Associates specialise in providing customer research data and is one of the biggest providers of independent market research for automotive OEMs. The methodology for carrying out the different market research surveys for vehicle attributes are presented within J. D Power brochures (Source: JD Power APEAL Executive Summary, 2010). The process includes sending thousands of surveys to new vehicle owners who have purchased a vehicle in the last 90-days. Alongside the survey, individuals are given a dollar incentive to take part in the survey. The surveys can include over 90 questions which enquire about vehicle

attributes and the Things Gone Wrong (TGW). An overview of the studies which are offered to automotive OEMs include:

- **Automotive Performance Execution and Layout (APEAL) Study -** The APEAL documentation states that the study focuses on, "*Measuring the appeal of new vehicles and owners satisfaction*". This study focuses on capturing the owner's perception of various features and attributes from the vehicle which range from the interior experience to how vehicle owners perceive the driving experience, in total there are 95 attributes which are evaluated. There is also opportunity for vehicle owners to highlight any problems or Things Gone Wrong (TGW) with each vehicle. In 2007 the APEAL study received 21% of the 459,375 surveys which were sent out which highlights the low response rate with mail surveys. It is suggested that the higher scores translate to more sales.

- **Initial Quality Study (IQS) –** The aim is of the study is, "*To provide manufacturers, suppliers and consumers with information on new-vehicle quality as defined by the voice of the customer*," (J. D Power IQS Executive Summary, 2007). The IQS study helps understand the problems and negative aspects received for a given vehicle.

Automotive OEMs can conduct their own in-house satisfaction surveys to ensure that they meet customer needs and may rely on more than one data source. Due to the lack of published literature of research which focuses on automotive satisfaction surveys, it is suggested that a study with an automotive OEM is carried out to ensure that this thesis contributes to knowledge.

2.5. Comparing Customer Research Approaches

Structured evaluations and market research methods share similar goals by aiming to understand what people want and how they behave (Gilmore, 2002). However, no research was found which focussed on attribute evaluations based in controlled laboratory testing environments and compared them to market research approaches. This review therefore broadened its scope to

examine similar tools to structured evaluations, e.g., user-focussed techniques from the human factors discipline.

Beers (2008) and Buckner (2008) commented that new approaches should be adopted which blend research techniques from both user-focussed techniques and market research approaches. User-focussed tools often share the similar criteria of structured evaluations, e.g., assessment of products using systematic questions in relatively controlled environments and understanding the usage of products. Buckner (2008) suggests that market research misses the context of customer experiences with the products, whereas user-focussed research can neglect valuable opportunities to learn about marketing effectiveness during the evaluations. Evaluations of products in customer research and market research have been suggested to be used together, however no empirical research was found to have tested these distinct environments for collecting customer research.

As automotive OEMs invest many resources to produce a vehicle through rigorous testing procedures spanning over 24 months (Weber, 2009) it is only at the end of the NPD that determines how successful the vehicle becomes in the marketplace. This creates a key research problem, and raises the question about what can be done to further understand how customers evaluate products between market research and structured evaluations, and if there is any knowledge which can help understand how customers evaluate products earlier in NPD. A summary of the differences between market research and structured evaluations is presented in Table 2.1.

Table 2.1: Methodological differences between market research and structured evaluations in the automotive industry

Approach	Sample Sizes	NPD Stage	Experimental Control
Market research	Large (>130)	Post-Purchase after NPD	Low
Structured evaluations	Small (<30)	Target-Setting in early NPD	High

It was also identified from the review that each approach (structured evaluations and market research) have differences in the way that they are conducted and therefore each has advantages

and disadvantages (Table 2.1). However, no existing research was found to date which provides an understanding of how each of the methods differ or indeed influence customer evaluations. Better understanding the approaches can provide a complete picture of customer responses earlier in NPD. No empirical research to date was found which compared structured evaluations with market research techniques. This provides an opportunity to conduct empirical research to compare these approaches of collecting customer data.

Understanding how assessors evaluate attributes at the post-purchase stages could provide knowledge in the form of important criteria used by vehicle owners to base their judgements on evaluating vehicle attributes. This could further enhance automotive experts current understanding of vehicle owners and their perceptions of vehicle attributes. This identified information could be beneficial for product designers and engineers working in the earlier stages of automotive NPD (Section 2.2.1).

The following question was raised after reviewing the available literature on challenges facing automotive OEMs:

Research Question 1) What are the strengths and weaknesses of the current usage of customer research data within automotive NPD and what are the current sources of data used?

Answering the question can identify the important issues facing the automotive industry when examining customer research data and potentially identify aspects of the customer which are currently not collected. Duke and Mount (1996) suggest that the results obtained from customer evaluations are not easily interpreted by the industry.

As market research approaches and structured evaluations occur at different stages of NPD and no available academic literature was found which compared the approaches, it would be valuable to further understand how the approaches compare in order to obtain up to date information about the customer needs.

A psychological approach could provide an in-depth understanding of how customers evaluate vehicle attributes in the methods identified in this review. Decision-Making tools could provide

a suitable comparison of ‘how’ customers evaluate automotive attributes in structured evaluations and market research. This would provide a novel comparison of the customer research approaches available to automotive OEMs, which would otherwise be investigated through an engineering perspective. Using a psychological approach however, will require a further review of the literature.

2.6. Summary

This chapter outlined the context of this research, which was set in NPD within the automotive industry. This review progressed to establish the importance of customer research within NPD. It was evident from reviewing the available literature, that there is a limited understanding of how structured evaluations compare to market research. It was also apparent from the review of customer research methods and available literature documenting the automotive NPD process that the need to compare structured evaluations with market research methods is evident from both the industry and research literature.

Structured evaluations are carried out early in NPD and require significant resources to develop vehicle attributes, it is currently not known how vehicle owners in the post-market stages the evaluate the product through automotive satisfaction surveys. This can create a problem which leaves automotive designers and engineers with a limited understanding of the issues vehicle owners experience having purchased the vehicle.

A comparison of structured evaluations and market research approaches through the available literature was compiled. The limited literature available on this particular research area identified an opportunity to carry out empirical research in order to understand differences between the two evaluation processes. Adopting a psychological perspective could allow an insight of how customers evaluate vehicle products in structured evaluations and market research. As the questions raised from this review are broad, a further review of potential psychological measurements, which can allow an in-depth understanding of how assessors take part in evaluations should be reviewed, e.g., decision-making.

Finally, it is not currently understood how customer research data sources are used within the industry. In order to ensure that this research remains valuable and uses evaluations representative of those used by the automotive industry, a preliminary study is needed with an automotive OEM which could identify additional insights facing the usage customer research data.

Chapter 3
A Review of Decision-Making Methods to Understand Customer Evaluations

3. A Review of Decision-Making Methods to Understand Customer Evaluations

3.1. Introduction

This chapter examines the psychological influences when individuals evaluate subjective stimuli which could be applied in product evaluations. Potential psychological constructs are evaluated to help identify potential comparisons which can be carried out between structured evaluations and market research approaches. Finally, this literature review critiques potential methods which can be applied to understand subjective evaluations of vehicle attributes.

3.2. Cognitive Psychology Approach

The previous literature review identified the importance to understand how vehicle attributes are evaluated by customers (Kidd, 1963; Thomke and Hippel, 2002; Meyer and Schwager, 2007). One of the disciplines which can be used to examine customer experiences in evaluations is through Cognitive Psychology. Eysenck and Keane (2005) classify cognition as the internal processes of the human brain which help make sense of our environments. Understanding cognition can help understand how individuals shape their attention, perceive objects, use memories and how they think (Sharp et al., 2007). Kidd (1963) elaborates on the potential human psychological factors which could be considered when investigating product evaluations:

- **Subjective Product Interpretation:** As products can consist of many attributes, how each feature is perceived by customers can vary greatly. It is suggested that a degree of distortion can occur between both customers and experts. This can result in certain stimuli becoming undetected by individuals, or being placed at a greater emphasis. Further research is needed to understand product interpretation from various customer groups.

- **Memory Limitations:** Kidd (1963) describes the limitations which can occur within memory, resulting in a limited capacity for participants, particularly in remembering complex and lengthy information streams. This shows that products and systems should be designed to consider the limitations of individuals' memory stores when a product is being used. Extensive research has already been carried out investigating the role of memory in product evaluations, particularly in time-based studies (Ganzach and Mazursky, 1995; Mital et al., 2001).

- **Decision-Making:** Individuals taking part in a task requiring one or more decisions may choose to select or reject information available to them. It is also suggested that the individual may use additional criteria combined with personal past experiences when selecting information as a basis for their decisions. Brehmer (1990) also reminds the reader that decision-making is a dynamic process where decision-makers can adapt to the information provided to them. Orasanu and Connolly (1993) report how decision-making research in the past has neglected the knowledge and experience used by participants and can conceptualise an ideal way of carrying out decisions rather than understanding what actually occurs. Currently there is a limited understanding of the information embedded within these knowledge structures and how they are used within decision-making tasks, particularly for automotive attribute evaluations.

These factors show the need to broaden our existing understanding of customers and how they perceive product attributes in evaluations. Cognitive Psychology is a suitable discipline to examine how participants take part in product evaluations used in this thesis (Chapter 2). Cannell et al. (1981) have mapped the cognitive processes involved in an evaluation which is presented in Fig: 3.1.

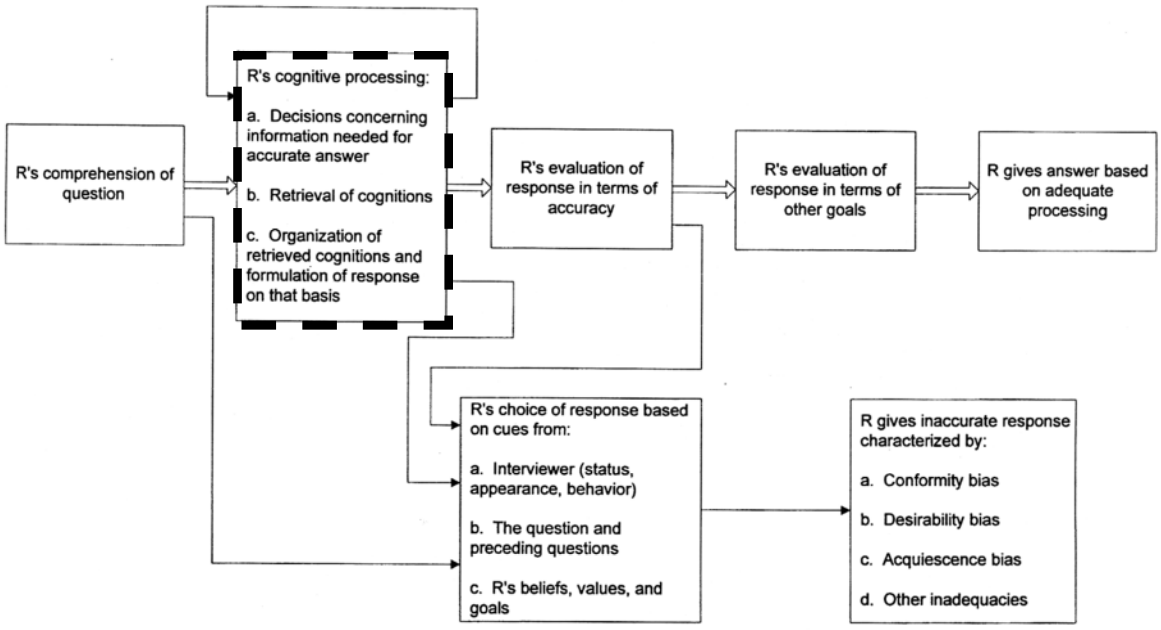


Figure 3.1: Mapping the Respondents (R) processes in an evaluation (adapted from Cannell et al., 1981)

The model (Fig. 3.1) highlights the cognitive processing stage as a core component which subsequently influences the response process for the evaluator. Further investigating how individuals make decisions could help understand the way individuals process the available information or knowledge during decision events (Orasanu and Connolly, 1993). As a result this could provide a suitable and practical opportunity to contribute towards applying a novel approach within the automotive industry and provide automotive product designers and engineers with a better perspective about how customers evaluate vehicles. Eventually, with further refinement OEMs will be able to focus on the important influences on customers from the start of the automotive NPD process (Chapter 2).

3.2.1. Decision-Making within Customer Evaluations

Eapen (2009) defines a decision as, "*A conclusion reached or an action taken regarding a present or future based event based on past, present or forecasted information*." Based on this definition, the current perspective of this research aims to understand the information assessors use in an evaluation setting, e.g., structured evaluations or market research.

Eysenck and Keane (2005) highlight the multi-component nature of decisions when describing judgements as a part of the decision-making process which involves the estimation and likelihood of events occurring. There are a number of decision-making analysis which have

been investigated such as making decisions under risk (Kahneman and Tversky, 1981), economic decision-making and examining choices (Nutt and Wilson, 2010). However, some choice based decision-making may not reveal new information used in evaluations by customers. Svenson (1979) advises decision-making may not always be fully understood by examining final choice decisions which have traditionally gathered attention from Judgement and Decision-Making researchers. Decision-making literature therefore can be broadly categorised into two areas. One of the areas focuses on heuristics and rationalised thinking during choice-based tasks (Kahneman and Tversky, 1981), and second focuses on understanding the decision-making events which occur in real-world settings, e.g., naturalistic decision-making (Lipshitz et al., 2001; Klein, 2008).

Influences within Decision-Making

Miller and van Cott (1955) have long established the roles of intervening criteria which can influence the decision-processor and as a result the overall decision, (Fig. 3.2).

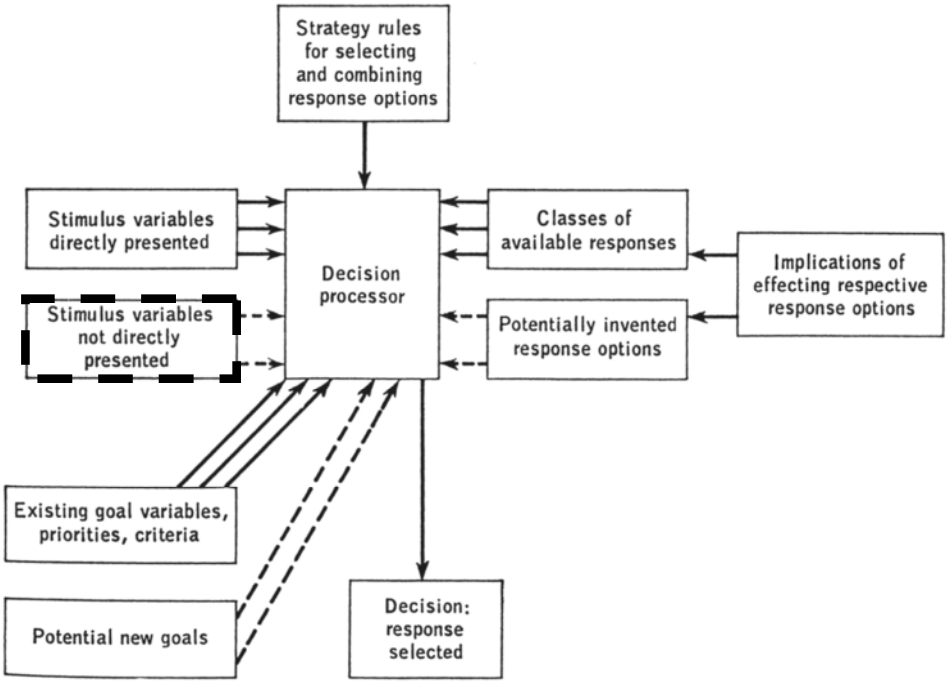


Figure 3.2: Factors involved in decision-making (Adapted from Miller and van Cott, 1955)

Within Fig. 3.2, the authors raise the awareness of understanding the stimulus variables not directly presented as part of the experiment. For example, stimulus variables may not be directly presented in an evaluation however, the evaluation process may elicit certain information to be

used in the participants decision-making process. However, Fig. 3.2 does not show the stages in which decisions are made. It is necessary to understand the cognitive stages which occur during an evaluation, which will be examined next.

Understanding the inaccessible information or criteria may need to be identified in order to understand the influence of evaluations. As this research is concerned with understanding the information or criteria used by customers during an evaluation of a vehicle attribute, it is important to further examine how information is processed in evaluations.

Examining the Decision-Making Process

The decision-making process revolves around four stages presented in Fig. 3.3 (Sudman et al., 1996; Tourangaeu et al., 2000).

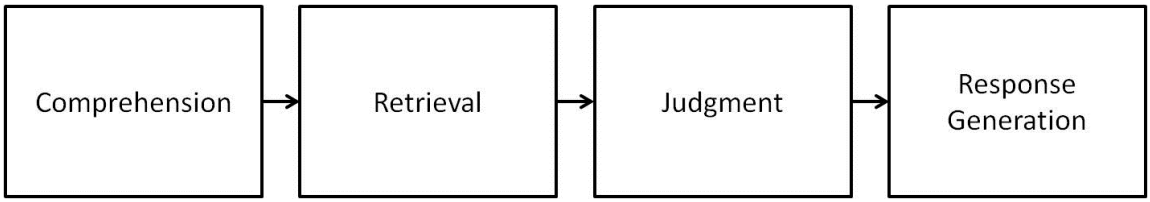


Figure 3.3: Four stages of a judgment making process (adapted from Sudman et al., 1996)

It is evident from documenting the response processes outlined by the authors that each decision-making step is dependent on previous steps. Suggesting that the eventual response made in the final stage is dependent on the information retrieved from either memory or information presented. Sudman et al. (1996) elaborate on each of the steps:

A. **Comprehend/Interpret:** In the first step, the individual needs to understand the environment, the task, and the stimulus presented. This stage helps individuals establish a set of boundaries and identify how and what information they need in order to answer the question.

B. **Retrieval:** This is the second stage which requires the individual to recall information from either the long-term/short-term memory stores. This stage allows the relevant information in the form of knowledge to be accessed. It is suggested

that this information shapes the decisions individuals make in an evaluation. Limited research has looked at identifying these knowledge structures.

C. **Judgment:** Once the relevant information is received from memory, the individual can take steps to determine if the information recalled meets the task requirements of the question being asked, this can include processes such as determining the level of occurrences of the retrieved information, to estimation strategies.

D. **Response Generation:** The final stage of the process culminates at generating the response. This is also a stage where individuals have conscious control to either omit or overestimate certain aspects of their information.

One of the challenges facing decision-making research is the difficulty in accessing the decision-making processes carried out which can explain why the knowledge structures or decision-making criteria customers use in automotive evaluations has not been researched. This identifies a potential gap in existing knowledge and provides a suitable opportunity for this research to examine the information which is used in the retrieval stages of decision-making processes during a given evaluation. The identified gap in knowledge can be used to establish the second research question in this thesis:

Research Question 2) How do the decision-making criteria used by assessors compare between market research techniques and structured evaluations?

Answering this question based on the available literature suggests new knowledge can be generated in this area which could also be valuable to engineers in automotive NPD to understand the issues customers face earlier in the product development and design phases. Eventually the knowledge can help engineers to improve vehicles and attain better evaluation responses from customers by being aware of how customers evaluate vehicle attributes. The next stage is to examine how to observe decision-making processes carried out by individuals in a valid and repeatable method.

3.3. Process Tracing Methods to Capture Decision-Making

This section will evaluate a number of Process Tracing methods (Schulte-Mecklenbeck et al., 2011) which can be used to examine the decision-making criteria used by assessors. The methods in this review can be assigned to naturalistic decision-making literature which are used to capture the knowledge used by customers while they make their decisions in real-life scenarios (Klein, 2008). The methods will also be evaluated for their suitability to be carried out in vehicle attribute evaluations.

3.3.1. Cognitive Interviews

Cognitive Interviews were designed to help obtain in-depth and accurate information from an individual (Memon et al., 1997). They have been widely adopted to assess information recalled by individuals and are even used in forensic settings (Kebbell et al., 1999). One of the methods used within Cognitive Interviewing is known as Verbal Protocols.

Verbal Protocols

Verbal Protocols have been used to understand the information used in the decision-making processes used by individuals to ensure evaluation questions are perceived correctly (Sudman et al., 1996; Beatty, 2004). Verbal Protocols reflect the thought processes assessors experience in a given task (Sirken and Schechter, 1999). When applied to a task, Verbal Protocols could help identify the criteria and knowledge which are elicited and used by participants (Schulte-Mecklenbeck et al., 2011). The technique requires participants to essentially 'think out aloud' their thoughts during a task which is under focus. Should the Verbal Protocol technique be applied during the task being carried out in its naturalistic setting, the technique is known as a Concurrent Verbal Protocol. Ericsson and Simon (1980) who pioneered the usage of the method, found that the most valid and accurate reports of Verbal Protocols were captured while a well-defined task was carried out.

Verbal Protocol elicitation methods have extensively been used to reveal decision-making used by individuals in surveys which have helped improve question construction and identify

misinterpreted questions, rectifying these have led to accurate and reliable responses from respondents (Sudman et al., 1995; Presser et al., 2004; Schulte-Mecklenbeck et al., 2011).

Verbal Protocols can allow the sequence of cognitive events that occur between the very first stimulus and the final decision outcome, to be captured and assessed (Kuusela and Paul, 2000). The resulting data can then also help understand the steps resulting in a certain decision. This can shed light on the way in which participant knowledge is used within the task being investigated.

In contrast to Concurrent Verbal Protocols, a second method known as a Retrospective Verbal Protocols can be used. This second technique encourages individuals to verbalise any thoughts that comes to mind, in a given task once it is completed. The 'think out aloud' process does not start until the participant has completed the task. Once the task is completed, participants are requested to recall how they made their decisions. The advantage of a retrospective protocol is that the process is perceived to have little, if any, interference with the actual task in hand. Kuusela and Paul (2000) however, found that Concurrent Protocols provided more accurate insights in comparison to retrospective data. Secondly, participants may rely on their memory to understand how they carried out a particular task and may omit some thoughts. The authors did however, find participants in a retrospective protocol to provide more statements about the final choice; perhaps due to the ease of recalling recent information (Kuusela and Paul, 2000).

Finally, Verbal Protocols have recently been used in a variety of scenarios including an automotive context. Walker et al. (2008) have used Verbal Protocols to understand situational awareness while participants use a virtual vehicle simulator. Verbal Protocols have also been used to pre-test questionnaires (Callegaro, 2005), which supports their usage in product evaluations.

Thought Listing Protocols

This procedure relies on participants to write down their thoughts rather than to verbalise them (Cacioppo and Petty, 1981). Similar to Verbal Protocols, it is suggested that the Thought Listing Protocol (TLP) approach can yield information about the cognitive responses or cognitive

structures (Cacioppo et al., 1997). This tool could be useful for identifying the most recent thoughts participants carry out in response to topics which may be sensitive in nature or scenarios where an interviewer may inhibit responses unintentionally. Sharing similar principles to Verbal Protocols, a TLP can be administered during a task (Concurrently) or after the task is completed (Retrospectively).

However, using TLPs could distort the naturalistic setting of a decision-making task, as participants will need to write down their thoughts on a device or notepaper. This can be difficult to implement when evaluating sound in environments such as interactive vehicle simulators, especially while driving. Nevertheless, TLPs have received limited attention for evaluating methods, and therefore may be carried out in addition to other Cognitive Interviewing methods to ensure a high level of validity which will be later discussed in Chapter 5.

3.3.2. Information Search Methods

The methods in this category follow a theme of identifying important information needed in decision-making tasks. Participants can select as much information as they wish. These evaluations allow researchers to understand the important criteria used in the decision-making processes used by participants, particularly in choice-based decisions (Payne, 1980). A variety of methods have been designed, which use various levels of technology ranging from information boards to Personal Computer (PC) interfaces (Payne et al., 1978; Jacoby et al., 1980). Recent methods can use physiological measurements to help improve the validity of information search methods (Wang, 2011) and will be evaluated in Section 3.3.3.

Active Information Search

An Active Information Search (AIS) experimental method consists of four stages which ultimately require participants to make a decision by the end of the trial. The method focuses on assessing how much information is required by participant in a given task, particularly for risk-based choices (Huber et al., 1997). The four stages of AIS include (Huber et al., 2012):

1) **Reading:** Participants are given brief information of a task in the form of a scenario description, which require participants to ask questions to receive extra information which can assist them in making the required decision.
2) **Questions:** Participants are given the opportunity to ask questions to attain more information and are recorded by the experimenter.
3) **Answers:** In response to each question, the experimenter provides the participant with pre-set answers. The authors suggest printing the answers on cards for standardisation.
4) **Decision:** Once the participant feels enough information is provided, the participant can make the choice as defined in the reading phase of the task.

Using an AIS method increases the likelihood of naturalistic decision-making which can include time constraints, ill-defined structures and changing goals (Oransu and Connolly, 1993). Using an AIS method encourages participants to ask questions on their own accord and captures the information unobtrusively in comparison to Cognitive Interviewing. However, using this method can be difficult in new research areas where pre-determined answers for Stage 3 are not defined. The evidence from the review suggests that the AIS method is more suited for verifying knowledge structures which have already been identified. More recent adaptations of the AIS method allow this method to be used for internet-based scenarios. This is known as "WebDiP" which allow participants to search for relevant information online (Schulte-Mecklenbeck and Neun, 2005). This tool can be suitable for assessing information used by participants for online based surveys and vehicle reviews.

MouseLab

The MouseLab method uses a computer programme which presents participants with a choice-based task. In order to make the intended choice, participants have the option of acquiring information to assist them in their decision-making choice. The values of information are hidden until the participant seeks the information by selecting the relevant option in the computer programme. An example of the display is presented in Fig. 3.4, which shows the

content of the ‘features’ option when the participant selects or hovers over it using the mouse or a pointing device of a PC.

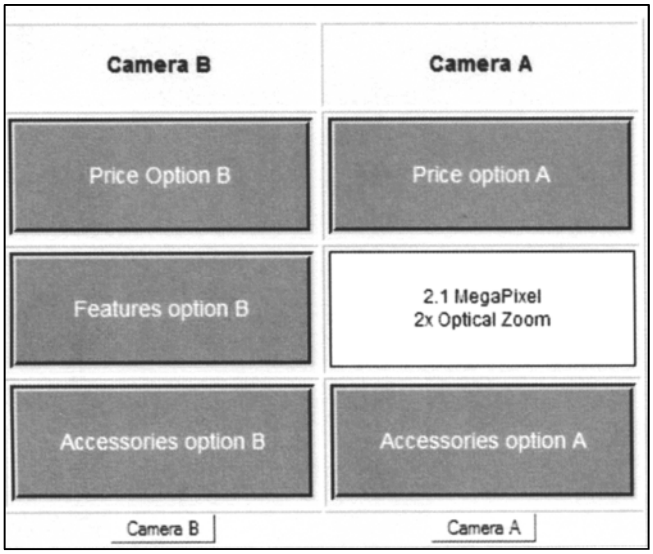


Figure 3.4: Example of a “MouseLab” experiment and an information square being revealed in order to select a camera (Source: MouseLab Website)

Participant responses such as the frequencies of selecting information and time spent examining each information can be collected and then later inferred to highlight the important criteria which influence product choice. One of the constraints with using this method is that the materials for each trial are restricted to choice-based evaluations and this method cannot be used to assess existing materials such as evaluation based tasks. They are perhaps suited to understand the purchase behaviour amongst choices between 2 to 10 alternatives and 2 to 8 attributes (Lohse and Johnson, 1996). Any options exceeding the recommendations may create difficulties for participants by increasing the complexity of the task. Additional choices also may add challenges for the software to present the attributes to the participants on the computer screen with MouseLab.

3.3.3. Physiological Measurements

These are potential methods which use physiological responses to understand human decision-making. As physiological measurements occur naturally and they are harder to mask than verbal responses and written responses, it is suggested that physiological measurement data could supplement cognitive studies. Physiological measurements can be captured in response to a range of stimuli. However, this is a relatively new area for understanding how measurements

attribute to decision-making processes (Schulte-Mecklenbeck et al., 2011). Further research could provide a better understanding of the interpretation of physiological measurements and still require a verbalisation element to make sense of participant evaluation processes in assessment based evaluations (Annett, 2002). It is beneficial to evaluate the physiological measurements in this review as they may be used in certain applications to extend research in decision-making.

Eye-Tracking

Following similar principles of acquiring information, Russo (2011) reports how the eyes provide a prominent sense for gathering information. Eye-tracking research can help identify where individuals direct their attention to a number of product features (Wang, 2011). Eye-tracking however, can only infer limited information for providing an insight into the knowledge structures used when participants answer a survey. However, eye-tracking can be used to understand product features which attract the attention of customers and possibly in a purchase scenario with customers. With the advancement of technology, eye-tracking equipment is becoming more user-friendly and could be used in external environments such as product showrooms or inside vehicles. Eye-tracking measurements can be carried out using head- mounted apparatus to measure visual attention from drivers and to assess fields of view when driving in a vehicle simulator (Nakayasu et al., 2007) or via dashboard mounted cameras to capture eye-movements such as gaze directions, blink rates and eye-lid positions (Apostoloff and Zelinsky, 2004).

Skin Conductance

Figner and Murphy (2011) highlight that the skin has electrical properties which can be measured by observing Galvanic Skin Responses (GSR) which is able to help determine emotional arousal through the electrical resistance in the skin. A higher arousal translates to a fall in resistance and a lower arousal causes a rise in skin resistance. The motivation for using such a method for understanding the decision-making is reflected through capturing the hidden influences which can occur when people make decisions due to the continuous and relatively uninhibited nature of our skins GSR.

The probes for conducting GSR measurements need to be in contact with the skin with relative stability. With the task of driving in structured evaluations such as on-road or simulated environments, using GSR apparatus can be restrictive and may cause discomfort to participants. With the added movement caused by the actions of driving may also affect the measurement data from this process.

3.3.4. Selecting a Process Tracing method to be used in Vehicle Evaluations

A summary of the methods which can be used in this research are:

- **Cognitive Interviewing –** Aims to capture the sequence of decision-making thoughts used in a given task. These methods can be used in a number of evaluations in a natural setting. However, Cognitive Interviews need to be run with scripts and designed verbal prompts to ensure repeatability and it must also be ensured that the participant is freely verbalising their thoughts.

- **Information Searching –** Relies on identifying information used by participants in evaluations. Special materials may need to be designed in the form of information grids which provide an array of choices to customers. This may not reflect what participants actually perceive in real-life. However an Active Information Search can present a real-life scenario and allow participants to freely question important issues. This is subject to information available to the researcher and it may hinder the discovery of new information from participants.

- **Physiological Measurements –** Can be used to identify the important stimuli which participants focus on by reading measurements in body responses such as GSR and eye-tracking. However, this does not necessarily reveal a deeper insight into the decisions being made. The equipment for this can also be uncomfortable for participants and costly. These methods can be used to further verify existing stimuli choices or configurations and used to assess for participant pleasure and arousal.

The suitability of each Process Tracing method should be based on the ease and level of interference on the sound evaluation method being carried out. Assessors should remain uninfluenced by the observation and that the vehicle evaluation remains in its naturalistic setting which is representative of how the manner it is carried out in the automotive industry.

Considering this essential requirement, physiological measurements will require a great deal of customisation to ensure that each stimulus presented to participants is presented in isolation to understand its influence on Arousal/Pleasure dimensions (Lang, 1995). Information search tasks can be an alternative method to use, however with some of the choice based tasks, the materials would differ greatly as to what is naturally presented to customers and the study would be limited to using an existing market research survey and a structured evaluation. Taking these factors into account suggest a Cognitive Interviewing method is used, as the materials for assessing the selected vehicle attribute will be unchanged and will remain to be representative of the method used in a real-world setting.

Using a Concurrent Verbal Protocol method could facilitate participants to talk about their thoughts and the decision-making steps that they use, revealing important information. It too can provide a vast wealth of information to designers and researchers who need to understand how customers respond to vehicle attributes.

3.4. Summary

This chapter identified the cognitive influences involved when participants take part in evaluations. Considering the research need for understanding the information embedded within the knowledge structures used in evaluations, the review identified that there can be additional sources of information which may have not been presented within the evaluation, yet can also influence product evaluations.

It was decided to focus on understanding the decision-making component of cognitive influences of participants taking part in vehicle evaluations. A range of techniques were also identified which provide an insight into the information used by participants as well as briefly considering the participant physiological responses of experiencing stimuli.

A number of Process Tracing techniques were reviewed with the aim of selecting a method which could be used in structured evaluations and market research. A Concurrent Verbal Protocol technique was selected to be used to identify the decision-making criteria used by individuals in evaluations of vehicle SQ through market research surveys and structured evaluations. Thought Listing Protocols (TLPs) could also be used to supplement a Verbal Protocol technique used in this thesis.

Chapter 4
Understanding Subjective Responses in Automotive Sound Evaluations

4. Understanding Subjective Responses in Automotive Sound Quality Evaluations

4.1. Introduction

This chapter presents a literature review of automotive Sound Quality (SQ) which was selected as the focal vehicle attribute in this thesis. This literature review evaluates the environments in which SQ evaluations are carried out. This chapter also examines the potential research opportunities to investigate decision-making in SQ evaluations which can help to understand the underlying criteria used by assessors in SQ environments.

4.2. Background into Automotive Sound Quality

Jennings et al. (2010) classify SQ as, "*Features or distinctive qualities in the sound other than the frequency or level*." SQ can be discussed in both technical/objective and perceptual/subjective terms (Rumsey and McCormick, 2009). One of the ways drivers can determine how a vehicle performs is through auditory phenomena (Plunt and Hellström, 2006). Auditory phenomena from a vehicle can be made up from the following:

- **Engine/Powertrain Sounds –** These sounds comprise of the engine mechanical sound, belt systems, and combustion sequences, which can be heard through the exhaust of the car (Cerrato, 2007).
- **Wind Noise –** This noise is caused by the wind flow over the car's bodywork (Cerrato, 2009).
- **Road/Tyre Noise –** This noise source is caused by interaction between the tyre and the road surface (Sottek et al., 2005).
- **Buzzes, Squeaks and Rattle Noises –** These noises originate from mechanical components, internal trim fittings such as the instrument panel, or caused from excitation forces while driving (Chen and Trapp, 2012).

The auditory phenomena experienced by drivers can play a vital role in the perception of many vehicle characteristics, e.g., comfort/enjoyment (Cerrato, 2009) and powerfulness/refinement (Jennings et al., 2010). Automotive OEMs therefore try to ensure that the sounds perceived by drivers and passengers deliver the targeted brand ideals which enhance the perception of the product (Lyon, 2000). The intended brand perceptions arising from sounds can be set as engineering targets early in NPD (Chapter 2).

Setting the optimum targets however can be a challenging task due to the continuous involvement needed to operate a vehicle and the subjectivity of assessor's responses. For example, driving manoeuvres such as steering and braking can have an influence on the customer's perception of vehicle sound, which could influence the perception of the vehicle (Amman et al., 2005). Vehicle SQ can be engineered to elicit positive perceptions and images amongst listeners towards how luxury or sporty a vehicle is (Genuit, 2004). The perception of a vehicle can also influence customer satisfaction, which is important in improving sales and to encourage customers to repurchase (Sottek et al., 2005; Vavra, 2002).

SQ in the automotive industry is important to customers. Market research statistics suggest that the top concerns for vehicle owners are acoustic related (Source: J. D Power VDS, Industry Summary, 2011). Nehl et al. (2006) suggest that the influence of SQ on customer perceptions is not only limited to those who drive luxury vehicles but for most vehicle segments. This has led the automotive industry to focus on improving vehicle SQ, as it forms an intrinsic part of a vehicle's experience (Özcan and Egmond, 2008).

4.2.1. Product Sound or Noise

Auditory phenomena which emerge from products can be further categorised into 'Product Sound' or 'Noise'. Noises are classified as unwanted auditory perceptions which have no function in a product. Product Sounds however communicate the functionality of the product (Pederson and Fog, 1998).

As noises do not add value to the vehicle, the approach of noise reduction is used to improve vehicle refinement (Harrison, 2004; Cerrato, 2007). OEMs can use objective measurements

such as Sound Levels (dBA) which are sufficient to address the problem of loud interiors and unwanted noise (Shin and Hatano, 2009). However, reducing noise may not necessarily add to the experience of driving the vehicle (Humphreys et al., 2009). Repik (2003) highlights that objective measurements are not enough to satisfy customer perceptions of the vehicle, as there are subjective components which need to be researched, and are covered in Section 4.4. The key differences between Noise and Product Sound are presented in Table 4.1.

Table 4.1: The differences between Noise and Product Sound (Adapted from Pederson and Fog, 1998)

	Noise	**Product Sound**
Character	Unwanted sound	Communicative
Function	No Function	Providing information
Approach	Control/limitation	Design/Engineering
Source of Measurements	Sound Level Meters	Assessors perceptions
Primary Descriptors	Objective measures Sound Pressure Levels (dBA), frequencies	Subjective measures, e.g., Powerful and Refined

Using Assessors instead of Sound Level Meters

One of the key differences between 'Noise' and 'Product Sound' is the involvement of assessors, who decide on how sounds are evaluated (Fastl, 2006). This raises the importance to understand the manner in which subjective evaluations are made by assessors. Efforts to understand the subjective components to date have included examining the semantic descriptors or language used by the assessors (Jennings et al., 2010). Although both acoustic and perceptual measures are needed to develop vehicle sound (Genuit, 2011), this research will focus on the subjective evaluations made by assessors.

4.2.2. The Relationship between Automotive Sound Quality and Satisfaction

The importance of vehicle SQ and its influence on assessors evaluations becomes clearer when examining the impact on customer satisfaction. Using principles of the Kano Model (Kano, 1984), Dunne (2003) mapped SQ elements with customer satisfaction (Fig. 4.1).

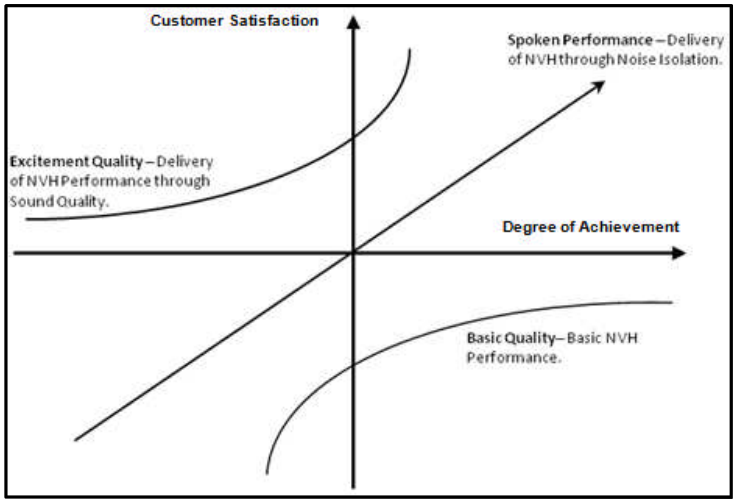


Figure 4.1: Mapping SQ functions with customer satisfaction (Dunne, 2003)

The Basic Quality level of performance eliminates squeaks and rattles (Noise). This relationship with customer satisfaction is limited and does not greatly increase with levels of achievement. The Spoken Performance element reduces further unwanted noises and vibrations. Spoken Performance has a proportional relationship with customer satisfaction, which increases as unwanted sounds are reduced. Should the sound provide excitement in the driving experience, customer satisfaction can increase dramatically, as shown in the Excitement Quality curve.

Mapping the acoustic properties of vehicle SQ with customer satisfaction shows vehicle sound has the potential to enhance the driving experience or even cause drivers to gain an impression of poor build quality (Plunt and Hellström, 2006). This further signifies the importance of understanding the subjective responses from assessors when engineering vehicle sounds. However, harnessing customer's subjective evaluations into NPD in a reliable and valid manner can be challenging. Methods used in subjective assessments of interior SQ are discussed next.

4.3. Subjective Assessments of Interior Sound Quality

In order to understand customer responses to automotive SQ, subjective assessments are carried out with methods which aim to capture responses in controlled and repeatable settings. As this thesis aims to further the understanding of how assessors make decisions in structured and unstructured evaluations, this review will also examine published research initiatives which

have used market research techniques in automotive SQ. Before reviewing the evaluations, it is important to define a sound stimulus which is used to capture SQ responses.

4.3.1. Selecting a Suitable Sound Stimulus

One of the sounds experienced by drivers can be sourced to the vehicle's powertrain (Kavarana et al., 2009). Powertrain sounds can be engineered to enhance the experience of driving and can contribute towards the perception of vehicle's performance (Blommer et al., 1997; Scheuren et al., 2004). Vehicle performance is ranked amongst the important criteria which customers could consider when purchasing a vehicle (Vrkljan and Anaby, 2011). This has led acoustic engineers to use sounds derived from the powertrain in automotive SQ evaluations.

To ensure the repeatability of the vehicle's operating condition when capturing the vehicle's powertrain sounds, acoustic engineers capture the auditory phenomena during a Wide Open Throttle (WOT) driving procedure. The WOT procedure involves the driver to select a gear and accelerate the vehicle by fully depressing the accelerator pedal. This allows a maximum level of powertrain sound to be captured from the vehicle's cabin. Using specialised recording equipment and strategically placed microphones, sound engineers can record the auditory phenomena which occurs inside the vehicle. The resulting auditory phenomena can be used as the stimulus which is presented to assessors in subjective evaluations such as listening rooms.

4.3.2. Structured Evaluation Environments Assessing Sound Quality

This section considers the environments known as structured evaluations, which are used to capture subjective responses from assessors for product attributes such as SQ. Due to the range of subjective responses elicited from vehicle sounds, it is important to ensure that the evaluations are repeatable and carried out under controlled conditions. Structured evaluations for SQ can be used to assess and compare sounds with semantics (Parizet et al., 2005).

These evaluations are conducted with structured components under laboratory conditions, which help to maintain the repeatability of the settings which can be used to set engineering/customer targets in NPD. Williams et al. (2005), stress that setting targets earlier in NPD can help to achieve both engineering performance requirements and the customer subjective perceptions

which are likely to reinforce the identity of the brand. Although many automotive OEMs each have their defined characteristics, which are investigated through individual SQ assessment regimes (Harisson, 2004), the environments needed to capture the subjective assessments of interior SQ remain similar. Each of the evaluation environments for assessing automotive SQ will be reviewed next.

Listening Room Based Evaluation

A listening room evaluation allows assessors to respond to a sound stimulus presented in an isolated sound chamber. A listening room can be arranged to reproduce sounds to assessors through electrostatic open headphones or loudspeakers, where they can respond via a data capture method. These data capture methods will be further outlined in Section 4.3.4.

Otto et al. (1999) recommends that listening rooms should provide a comfortable space for the assessor by ensuring that any ambient noise, décor and air circulation settings help make the assessor feel comfortable. Their paper provides guidelines to reduce the impression of a clinical setting, which can cause assessors to experience apprehension in a listening room. The guidelines can also encourage listening room evaluations to become standardised. The isolated sound chamber of the listening room further helps to ensure that external noises do not influence the presentation of the sound stimulus.

One unique advantage of the listening room environment is the possibility to present sounds from newly designed concept vehicles, which have not yet been manufactured (Jennings et al., 2010). Assessors can respond to the sound stimulus in a listening room through a variety of methods such as keypads, computer interfaces or even using paper based methods. An example of a listening room environment is shown in Fig. 4.2, which shows a set-up using a keyboard and touch-screen interface.

Figure 4.2: A listening room based in the Product Perception Laboratory at The University of Warwick

One of the drawbacks for using a listening room is the lack of accompanying phenomena which occur during the operation of a vehicle, e.g., vibration (Amman et al., 2005) or visual stimuli. This means that the sounds experienced in a listening room are only evaluated in isolation.

Using a WOT sound stimulus in a listening room can also be regarded as a limitation. The presentation of WOT sounds in evaluations is regarded to be passive as the assessors have no interaction with the sound stimulus. Secondly, WOT based sounds may not provide assessors with the representative or complete experience which can occur over a driving cycle (Jennings et al., 2010). This could result in a detached experience between the assessors and the sound presented without any operational inputs, e.g., braking, steering, and acceleration (Williams et al., 2007).

On-Road Structured Evaluations

In order to allow assessors to fully experience the phenomena and stimuli occurring when driving a vehicle, an on-road evaluation can be used. An on-road based evaluation involves assessors driving a test vehicle on a designated route/drive cycle during which feedback and evaluations of vehicle attributes, e.g., sound, ride comfort or handling, are obtained. Using on-road environments allows assessors to fully experience a vehicle and the phenomena which can occur when driving, e.g., acoustics and vibrations, (Amman et al., 2005). It also provides

assessors with the opportunity to experience sounds as driving manoeuvres are performed, over various road surfaces and operating conditions (Repik, 2003).

Although on-road structured evaluations can provide assessors with the experience of driving vehicles, these evaluations suffer drawbacks. For example, it is difficult to evaluate multiple vehicles due to time and resources needed to transfer equipment from each vehicle. This makes it time consuming to experience vehicles one after the other, which can easily be achieved in a listening room (Jennings et al., 2005).

The vehicle also needs to exist in the form of a prototype or production vehicle before it can be evaluated on the road. This creates a challenge to assess sounds for conceptual vehicles which have not yet been signed off by the engineering team. Furthermore, adjusting the sounds on prototypes requires a series of engineering changes to be made to the prototype which can also escalate costs. A prototype could cost in the region of $500,000 each which is a liberal estimate (LMS Whitepaper) and does not take into account the costs needed in setting up the NPD process. Traffic and weather conditions also make it difficult to ensure repeatability between driving conditions for each assessor.

Interactive Vehicle Simulator Evaluations

Before the development of vehicle simulators, on-road testing was the only method available for assessors to fully experience the driving characteristics of vehicles (Giudice et al., 2006). In order to overcome the passive nature of listening room evaluations and to control external influences such as traffic and weather, Noise, Vibration and Harshness (NVH) interactive vehicle simulators can be used to capture how assessors experience a range of vehicle sounds, noises and vibrations. NVH vehicle simulators can allow assessors to experience a range of operating conditions without the need for OEMs to fully develop a working physical model of the vehicle. A NVH vehicle simulator is based on an existing vehicle facing a projector screen that allows assessors to drive in a virtual environment (Fig. 4.3).

Figure 4.3: An interactive NVH vehicle simulator

Depending on how assessors drive in the virtual environment, the simulator's software can configure and present sounds via electrostatic open headphones, which also allow assessors to experience the additional noises through the cabin. Assessors can drive using the throttle, brake and gear inputs in a variety of driving scenarios which can allow a more thorough and representative evaluation (Kavarana et al., 2009; Williams et al., 2007) in experimentally controlled conditions (Pielemeier et al., 2001; Jennings et al., 2010). Assessors can also input their responses via similar methods to listening room evaluations. The vehicle simulator based at the University of Warwick included a touch screen interface based on the front passenger seat of the car (Fig. 4.4):

Figure 4.4: Data capture hardware inside the vehicle simulator

Jennings et al. (2005) highlight the advantage of being able to evaluate a number of vehicles in a NVH vehicle simulator, unlike on-road evaluations. Allowing non-experts to be able to take part in an evaluation is another benefit of using vehicle simulators (Williams et al., 2007), which can be safer than letting lesser-experienced drivers on-road.

However, the flexibility in a NVH vehicle simulator can also cause difficulties for all drivers to experience the same stimuli at specific points in the drive cycle. One way to overcome this is to have a Fixed Drive Cycle within the simulator which will present assessors with the same sound and visual stimuli regardless of their behavioural input. This raises the question of how assessors take part in free-driving settings within simulators?

Jennings et al. (2010) identified two distinct behavioural strategies which were adopted by assessors in a free driving mode setting in an interactive NVH vehicle simulator. When assessing the 'powerfulness' of a sound, assessors were found to perform greater frequencies of accelerations which resulted in sounds similar to the WOT stimulus. In contrast, during refined based assessments, assessors used high speed and stable driving operating conditions.

Driver behaviour can be observed as the inputs within the simulator can be recorded by the simulator software as they occur. This can identify the behaviour carried out in subjective evaluations which may not be observable for listening room based evaluations. Therefore, behaviour and perhaps other evaluation criteria cannot be directly be compared to other structured evaluations through existing methods and multi-disciplinary approaches need to be considered, e.g., the use of Verbal Protocols to understand the influences in evaluations.

Summary of Structured Evaluation Environments

This section has outlined the environments which are available to OEMs in order to capture the subjective responses from assessors. A summary of the environments to assess SQ, from the available literature is presented in Table 4.2.

Table 4.2: Listing the advantages and disadvantages of sound quality environments

Environment	Summary	Advantages	Disadvantages
Listening Room	Controlled environments to capturing assessor response to SQ	▪ Many vehicles can be assessed including concept vehicles ▪ High control and repeatable	▪ Passive sound playback ▪ Environment lacks full phenomena experienced in driving
On-Road	Evaluations take place in a test vehicle where assessors make evaluations on a designated route	▪ A range of operating conditions in full context is experienced	▪ External variables, e.g., weather and traffic can cause the repeatability to suffer ▪ Time consuming ▪ Vehicle must exist and changes need to be engineered and no back to back evaluations
Vehicle Simulators	A full vehicle simulator uses a video projector and a test vehicle, assessors can drive in a virtual environment. The simulator requires all the behavioural inputs needed to operate a vehicle. A desktop-version can also be used which includes a steering wheel and pedals	▪ High control and repeatable ▪ A number of vehicles can be assessed ▪ Concept vehicles can be driven and changes are easier to make ▪ Allows back to back evaluations	▪ Assessors may be inclined to take more risks in a simulator

One of the drawbacks which applies to the environments in Table 4.2 are limited sample sizes. Alternatively unstructured methods, e.g., market research, can be used to collect customer responses for vehicle attributes from many vehicle owners. However, there are no sounds presented and it is not fully known how assessors evaluate sound attributes in market research surveys.

Researchers need to ensure that the evaluation environments provide repeatable conditions and to identify methods which accurately capture the responses from assessors. In order to identify

the most suitable environments and to develop improved methodologies to collect customer responses, comparisons have been made between structured evaluations. Comparisons between listening room evaluations and NVH vehicle simulators have been carried out and researchers have found NVH vehicle simulators to achieve a higher consistency of results in comparison to a listening room evaluation (Williams et al., 2005; Jennings et al., 2005; 2010). Schulte-Fortkamp et al. (2006) speculate that the added context in interactive simulations is a key factor. Subsequent research by Kavarana et al. (2009) supports the usage of simulators as an alternative and more representative method to listening rooms when assessing SQ.

Researching methods has helped to design guidelines for conducting evaluations of SQ in listening room environments (Otto, 1999) and interactive NVH vehicle simulators (Jennings et al., 2005). However, the focus has not been extended to understand how structured evaluations compare to post-market research methods of evaluating vehicle attributes which creates a gap in knowledge. Understanding this gap in knowledge can help OEMs to develop better vehicles and maintain favourable market research statistics by understanding how assessors and their evaluations compare in each setting.

4.3.3. Unstructured Evaluations - Market Research

As market research surveys are also used to collect customer responses towards vehicle attributes. This caused the review to direct its attention towards understanding research which investigates SQ evaluations using market research. A benefit for using market research is that they can draw upon larger sample sizes for collecting customers responses.

A study by Dunne et al. (1998) remains the only initiative found to date which focused on understanding SQ listening room tests and market research. Their paper suggests automotive employee's impressions may not fully represent customer's impressions of powertrain SQ due to the complexity of the vehicle's interior environment and the diverse range of customer requirements. In their study, Dunne et al. (1998) examined the perceived imagery and powertrain scores of five vehicles. They found a positive correlation between a sound evaluation and market research. This suggests that structured evaluation quantitative scores can predict

those in a market research setting. Although a correlation between structured evaluations and market research was found, it does not reveal the manner in which customers evaluated the vehicle sound. Furthermore, additional research would have to be carried out to determine the strength of the correlation in subsequent evaluations.

Dunne et al. (1998) suggests using experts to predict customers is not ideal. Their paper further questions the involvement of experts such as the Vehicle Assessments Group (VAG) in the evaluations who are trying to predict and represent customers. Although, customer-employee research was found to correlate between employee and customer satisfaction (Bernhardt et al., 2000), a positive correlation between results does not reveal the evaluative criteria customers hold and cannot be compared through quantitative data alone. From the broader customer satisfaction literature, it is regarded that employees can have different viewpoints to customers (Vavra, 2002).

Understanding subjective evaluations made by assessors in market research and structured evaluations for SQ remains a novel research topic. Developing new knowledge in this area could help to further the understanding of the implicit information and evaluation criteria used by assessors in SQ evaluations, which can be difficult for designers and engineers to interpret. A psychological approach could capture the evaluative criteria and provide interpretations of the results which could fill this gap in knowledge.

4.3.4. Data Capture Methods

This section will consider the data capture techniques which are used within sound evaluations and examines the scales and instruments used to capture the subjective responses from assessors.

Magnitude/Direct Estimation

This method involves an ‘anchor sound’ and the other ‘test sounds’ (Biermayer et al., 2001). The ‘anchor sound’ remains consistent throughout the trial and assessors are requested to rate the ‘test sound(s)’ in comparison to the ‘anchor sound’. It is suggested that this method has the

advantage of allowing researchers to distinguish between smaller variations in assessors responses (Fastl, 2006) which subsequently can provide greater consistency in responses.

Paired Comparisons

Assessors using a paired comparison based scale are presented with two sounds. Assessors are requested to select one of the sounds which they feel fulfils the semantics presented in the questions (Biermayer et al., 2001), e.g., Assessors have to select which of the sounds is more powerful. As this method requires a choice input, it is particularly useful for non-expert assessors. However, Blommer et al. (1997) found evaluation performance using a paired comparison test had lower repeatability in comparison to Semantic Differential based evaluations.

Semantic Differential

Semantic Differential scales were established by Osgood (1967) where bipolar adjectives are used at opposite ends of the scale, e.g., quiet/loud, weak/powerful and conservative/sporty (Blommer et al., 1997). These adjective pairs can be used across a numbered scale (Otto, 1997). An example is shown in Fig. 4.5, which is based on a 10-point scale.

Figure 4.5: Semantic Differential scale

Summary of Data Capture Methods

Previous research has compared data capture methods to ensure that researchers and SQ experts use the most repeatable methods (Blommer et al., 1997; Guski, 1997; Bodden, 1998; Giudice et al., 2006). Table 4.3 presents a summary of the key data capture methods used in structured evaluation environments with strengths and weaknesses.

Table 4.3: Summary of the data capture methods used in sound quality evaluations

	Description	Advantages	Disadvantages
Magnitude Estimations	Allows assessors to make a comparison of a 'Test sound' with an 'Anchor sound'	▪ A number of sounds can be evaluated	▪ Unsuitable for identifying small differences in the stimulus ▪ Difficult for non-experts
Pair Comparison	Assessors are presented with two sounds and need to select one sound which best matches the question	▪ Easy for assessors ▪ Suitable for identifying small differences	▪ Time consuming Assessing six sounds can take up to 40 minutes (Giudice et al., 2006) in order to test all possible comparisons of sound-clips
Semantic Differential	Bipolar adjective pairs are used across a scale which can be numbered or without depending on the expertise of the assessors (Otto, 1997)	▪ Can be used with non-experts	▪ Deciding semantics can be challenging ▪ Assessors may use 'internal' interpretations of the scale (Blommer et al., 1997)

4.4. Understanding the Subjective Responses from Assessors in Sound Evaluations

This section reviews the literature to develop an understanding of the underlying criteria assessors use in SQ evaluations. Otto (1997) and Fastl (2006) remind researchers examining SQ, that the ultimate judge of the sounds is the assessor who decides which sounds relay the appropriate characteristics. However, understanding and capturing these perceptions from assessors can be challenging due to the subjective nature of SQ. Van de Ponseele and Adams (2001) describe that the 'human factor' can be illusive when evaluating the perception of sounds, which justifies incorporating novel approaches to examine the underlying criteria or decision-making criteria in SQ evaluations.

4.4.1. Methodologies to Assess Subjective Evaluations

The review will look at how existing methodologies which currently provide researchers with a procedure to assess the subjective evaluations of assessors. A methodology outlined by Cerrato (2007) could be adopted to set targets within NPD and is shown in Fig. 4.6.

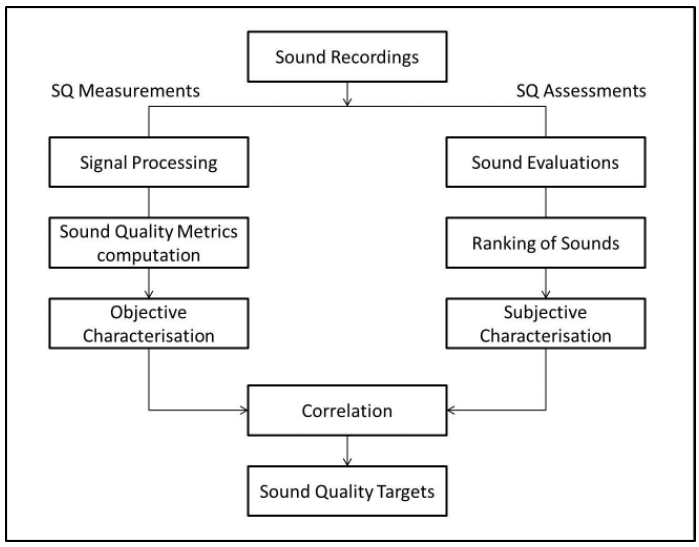


Figure 4.6: A SQ methodology which combines objective measurements and evaluations from assessors (Cerrato, 2007)

Cerrato's (2007) account reveals limited guidelines or suggestions on the subjective evaluation of SQ other than ranking sounds using paired comparisons. A study by Schulte-Fortkamp et al. (2006) presented more detail on the use of qualitative components in SQ evaluations which could provide a richer insight into responses from assessors. Their paper reports using Grounded Theory (Corbin and Strauss, 2008) to analyse transcripts which was incorporated into their methodology through semi-structured interviews. The broader process mirrors the methodology outlined by Cerrato (2007).

In a similar effort to understand the descriptors of sound, Genuit (2011) implemented a verbalisation technique to capture the sensory descriptors or language used by assessors in SQ evaluations. The methodology outlined by Genuit (2011) is illustrated in Fig. 4.7.

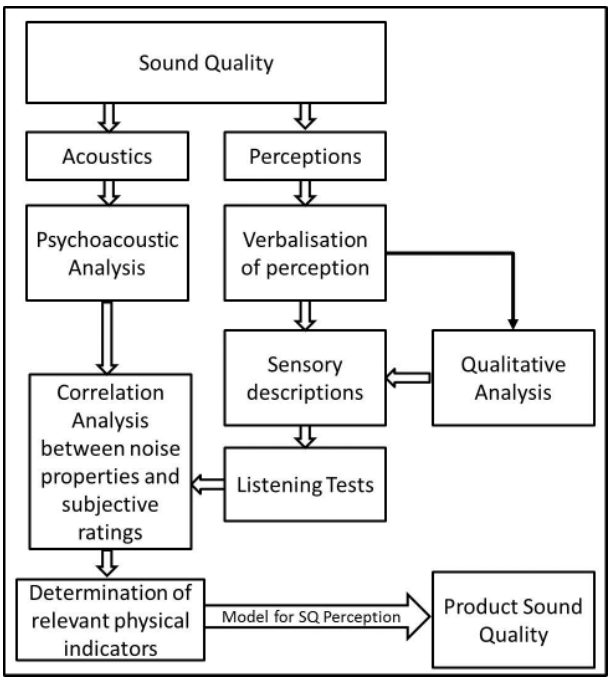


Figure 4.7: Outlining the process for defining SQ, (Genuit, 2011)

In a review of methods and techniques used in automotive SQ, Jennings et al. (2010) suggest that previous research efforts which aim to understand the underlying nature of SQ, focus on the language or semantic descriptors used by assessors.

4.4.2. Understanding the Language Used by assessors in Sound Evaluations

Assessors in descriptive and language based SQ studies have been told to *describe* rather than to *evaluate* the sounds which could result in differences in assessor's perceptions of SQ. For example, Altinsoy et al. (2012) carried out a Verbal Protocol elicitation technique in a structured evaluation based in a listening room. Their study focussed on understanding the language or 'semantic space' held by customers when evaluating vehicle sound. Assessors were requested to describe the auditory impressions from a number of behavioural contexts. As a result, the language used by assessors were categorised into four themes which are presented in Table 4.4.

Table 4.4: Description of the language assessors used in vehicle listening test evaluations (Altinsoy et al. 2012)

Study	Method	Categorised Language	Description
Altinsoy et al. (2012)	A Verbal Protocol method was carried out for a listening test based experiment which examined the language or semantic space used by customers when evaluating vehicle sounds across a number of behavioural scenarios	Signal	Terms related to the sound signal
		Physical Properties of Product	Comments related to the vehicle, e.g., luxurious, small or light
		Emotional terms	Language such as threatening or aggressive
		Association with Product	Sporty or luxurious

In order to further understand the underlying subjective nature of SQ, Jennings et al. (2010) investigated a range of semantics used in SQ evaluations in order to understand the language of sound perception. By investigating a range of 12 semantics, Jennings et al. (2010) identified powerful and refined as the two underlying dimensions which accounted for a significant proportion of variance in their data set, which can be used to help reduce the challenge of transforming the subjective evaluations from SQ into engineering specifications.

By focusing on the language used by assessors to better understand how automotive SQ is perceived could develop an improved understanding to help develop scales and semantics to evaluate sound. However, it could differ from the psychological approach adopted in this thesis which is focussed on how evaluations are made and the criteria used. Blauert and Jekosch (1997) identify the importance of psychological components which are involved in SQ evaluations such as the role of cognition, action and emotion. They suggest that any knowledge resulting from these psychological sources could complement the existing understanding of sound evaluations. This viewpoint was established in Chapter 3, which identified the need to define knowledge structures which could shape judgements and decision-making in evaluations for automotive attribute evaluations.

4.4.3. Decision-making in sound evaluations

Although understanding the decision-making information used by assessors was identified in Chapter 3, it is important to understand if any research within SQ has examined how assessors evaluate automotive sounds. Dürrer and Jekosch (1998) support the motivation in this thesis to

identify the information which could be triggered by the perception of a 'Product Sound' as a way to further existing knowledge, has not fully been achieved through existing studies. Williams et al. (2007) also highlight the need for further research to understand the decision-making processes used by assessors in evaluations, which contributes towards the identified gap in knowledge. Bodden (1997) suggests that the influencing factors on SQ judgements are related to:

- **The source (product) –** Factors related to the source or product which could represent an image**.**
- **The situation–** Factors of the situation could also be used when judging product sound which could be used in a specific situation.
- **The person –** Factors related to the person making the evaluation that can include Expectations, Motivations, and preferences.

However, the influences identified by Bodden (1997) are based from the literature and not empirical evidence. Empirical research to identify influences in assessor's judgement and decision-making of SQ is sparse.

From the limited empirical research available, Fry et al. (2004) conducted a study which included a qualitative component in understanding how customers make decisions in automotive SQ evaluations in a listening room. Their study captured the reasons behind customers' choices which were made using paired comparisons (Section 6.3.4). Keywords were extracted from assessor's reasons when selecting a sound which was (i) more powerful, and (ii) more refined. The keywords consists of descriptors which reveal an insight of why certain sounds can be chosen over others which could be valuable in designing the correct sounds suited for customer. Key terms extracted from transcripts included, accelerate rate, loudness and powerful were identified as the highly ranked descriptors. However, the keywords by themselves provide a limited insight of the influence that the method has on the choice made by assessors. An investigation of the total transcripts could provide further insights of the influence the method has on assessor's decisions.

In a one-off pilot study, preliminary psychological based constructs were adapted to understand assessor's evaluations processes for an on-road evaluation. Giudice et al. (2009) and Humphreys et al. (2009) proposed a series of influences in a person's opinion forming process of SQ which include:

- **Self-image and Personality –** Depending on the locus of control, evaluators may have a tendency to attribute events to external factors not in the control of the individual, e.g., the role of luck or chance. The tendency to seek sensations is also suggested by the authors which contributes to this influence. The role of an individual's self-concept is also suggested to contribute towards the assessor's perception of the vehicle.

- **Their knowledge of the brand –** Individuals pre-expectations of the brand may impact how the vehicle is perceived. The influence of advertisements was not examined in their paper but may also contribute to this influence.

- **Emotional responses whilst driving –** The authors suggest emotions can occur while driving and influence the individuals opinions formed about the vehicle.

- **Driver preferences, needs and demographics –** Individuals will consider the needs satisfied by the vehicle, including their demographics such as age, gender and income.

- **Experience of appraisals –** The authors highlights how customers may evaluate a vehicle differently from an expert, e.g., NVH Engineer/Vehicle Evaluation Team.

- **Their behaviour and responses during the appraisal –** The authors suggest that the way an individual drives a car will also influence the manner in which the vehicle will be evaluated.

In Humphreys et al. (2009) pilot study, automotive experts took part in an on-road evaluation of SQ. During the evaluation, assessors were asked to verbalise their actions, motivations and impressions when evaluating the sound of the vehicle. Pre and post driving questionnaire assessments which aimed to identify the influences on the opinions of assessors were collected.

It was found assessors used specific behavioural conditions to assess the SQ of the vehicle for example:

- Country lanes were used to assess full load accelerations, i.e., full throttle.
- Motorways were used by experts to assess road and wind-noise.
- Powertrain SQ was found to be evaluated by sequentially applying and releasing the throttle in a high gear at high speeds.
- Urban areas were used to determine gear whine, rattles and squeaks.
- Broken road surfaces were used to assess road impacts and cabin vibration.

The evidence suggests 'behavioural' scenarios can play a role in SQ evaluations in an on-road evaluation. However, taking part in an on-road evaluation may naturally encourage individuals to use different behavioural elements to experience the vehicle. Understanding the influence of a method for the first time can be difficult to interpret without making a comparison. To understand if 'behavioural' scenarios or other information is used by assessors in structured evaluations can be difficult to determine, yet is important to understand the influence of the SQ methods on assessor's evaluations.

Capturing and understanding the thoughts and decisions made by individuals could reveal an insight of the inner-workings assessors use in evaluations as well as to identify the influence of methods on assessors. This can also help to identify the information used by assessors in structured evaluations and market research which can be acted upon earlier in NPD. Using a psychological approach to examine assessor's decision-making could also provide a comparison between the SQ methods and market research which benefit from relying on rigorous process tracing methods that are researched in cognitive psychology. The approach could identify the information used by individuals in interviews and evaluations (Sudman et al., 1996; Presser et al., 2004). Furthermore, the lack of research found for market research survey assessments structured evaluations provide an opportunity to generate new knowledge which can improve the understanding the manner in which individuals evaluate sound in structured evaluations and market research.

4.4.4. Summary of initiatives which examine the subjective responses in Sound Quality evaluations

Table 4.5 presents a summary of previous research which have aimed to examine the underlying subjective perceptions of assessors in SQ evaluations.

Table 4.5: Previous research which has investigate the underlying criteria of subjective sound evaluations

Source	Study Method	Findings
Fry et al. (2004)	The rationale behind jurors choices in automotive sounds were investigated in an interview.	Key words from reasons behind powerful choices were identified.
Schulte-Fortkamp et al. (2006)	Collected articulated comments of feelings, emotions and impressions during a driving evaluation and in an interview.	Proposed the use of grounded theory to assess transcripts of verbal data.
Giudice et al. (2009) and Humphreys et al. (2009)	Proposed a framework which identifies factors which can influence the opinion-forming processes of evaluators. An on-road structured evaluation was carried out with automotive OEM employees.	Identified driving behaviours which are used by assessors to evaluate SQ.
Jennings et al. (2010)	Provided a review of the underlying semantics used in SQ with a principle component analysis and factor loading plots to identify the semantics which accounted for the most variance in SQ evaluations.	Identified 'Powerfulness' and 'Refinement' to be the underlying dimension of SQ from a range of semantics.
Altinsoy et al. (2012)	Identified language used in a Listening Test by customers evaluating vehicle sound, by using a verbalisation approach.	Identified 4 categories of language (signal related, physical properties of cars, emotional terms and association with vehicle.

These reviewed papers support the current motivation for understanding assessors' evaluation criteria for SQ evaluations. Achieving these insights could allow NVH experts to anticipate information which customers use as evaluation criteria earlier in NPD. Table 4.6 presents the existing research carried out to understand the underlying criteria used by assessors in structured evaluation environments and market research.

Table 4.6: Existing research which has focussed on understanding the criteria assessors use in evaluations of SQ for the available environments

Listening Room	On-Road	Interactive Simulator	Market Research
Fry et al. (2004)	Giudice et al. (2009) Humphreys et al. (2009)	Jennings et al. (2010)	No evaluation based Studies

4.5. Identified Areas for Research within Sound Quality Evaluations

This section presents questions which were raised in this literature review. The answers could generate valuable new knowledge to extend the current understanding of how non-experts evaluate automotive sound through the available methods to the automotive industry.

How do the decision-making criteria used by assessors compare between market research techniques and structured evaluations?

This review raises the need to understand how assessors evaluate automotive SQ in each evaluation method used in NPD. Understanding the decision-making criteria can provide one of the ways to identify the information used by assessors in each evaluation. Chapter 6 will help to determine insights from experts and to identify what information they will value from potential customers when evaluating product attributes. This can help to develop a better insight of how customers think about vehicles which was an insight needed to close the gap between automotive experts and non-experts.

What can we learn from non-experts to further understand how sound is evaluated in structured and unstructured environments?

Williams et al. (2007) suggests customers can find it difficult to fully describe the sound through traditional SQ approaches, e.g., listening rooms, which could prevent the automotive industry to fully understand customer issues to set their satisfaction targets in NPD. Literature focussing on the evaluative criteria to date has only relied on experts and in on-road evaluations through a pilot study (Giudice et al., 2009). In order to capture data from individuals

representing customers, using non-experts (automotive) in structured evaluations and market research evaluations could progress the current state of knowledge and help engineers to understand the influence of methods on potential customers when interpreting the important concerns facing customers in post-market stages.

4.6. Summary

The aim of the review was to establish the methods which can be used to understand the subjective evaluations made by assessors in SQ evaluations. The review progressed to shed light on the influences on assessors when they subjectively evaluate SQ in vehicle NPD. Subsequently this literature review has brought to light potential research opportunities which can generate relevant knowledge through understanding how the structured evaluation settings compare to market research in terms of decision-making criteria. Understanding the decision-making of vehicle sounds evaluations from customers can provide knowledge towards enhancing the perception of the driving experience and can help engineers to improve vehicles and results obtained in evaluations.

The following conclusions are reached as a result of this review:

- There is a need to understand the influence of the sound environments on assessors subjective assessments, e.g., 1) when no sound stimulus is presented (market research), 2) when sound is the only stimulus presented (listening room) and 3) when a full range of driving stimuli is presented in a virtual environment (interactive vehicle simulators).

- Understanding these subjective responses from customers (non-experts) could provide knowledge towards enhancing the perception of the driving experience and hence could help engineers to improve vehicles.

Chapter 5
Research Methodology

5. Research Methodology

5.1. Introduction

This chapter establishes the methodology adopted to ensure that the research questions and objectives are met in a reliable and valid manner. The chapter addresses data collection issues and how the results were analysed. Steps to maintain the ethical compliance of this research are also outlined.

5.2. Research Rationale

Chapter 2 identified a gap in knowledge when examining how assessors evaluate vehicle attributes in structured evaluations and market research, in addition to whether assessors evaluated vehicle attributes differently in each approach. Using a psychological approach and implementing a Verbal Protocol technique was suggested by the literature (Chapter 3) to provide an insight to allow the influences customers experience and their decision-making criteria to be observed.

In order to allow an in-depth investigation of the differences between structured evaluations and market research, it was decided to focus on a vehicle attribute which could be used to investigate both customer research approaches and could also be used to analyse customer responses for the same vehicle attribute under evaluation. Automotive SQ was selected as the focal attribute of this investigation. An in-depth review of automotive SQ methods was carried out in Chapter 4 to identify the current state of knowledge regarding the use of structured evaluations and market research to collect customer responses. The gap in knowledge regarding how customers evaluate vehicle attributes between structured evaluations and market research from Chapter 2 was again identified in the applied area of automotive SQ and hence provided the opportunity to carry out empirical research which is discussed in Section 5.4.

Due to the lack of literature available which assesses decision-making criteria between structured evaluations and market research, this thesis provides value to automotive OEMs in

addition to academia because it focuses on further understanding methods which are used for benchmarking competitor vehicles.

5.3. Research Questions and Objectives

This research aims to understand how automotive customers evaluate vehicle attributes in structured evaluations and market research in SQ. This research aims to answer the following questions with an explanation of the research carried out:

Research Question 1) What are the strengths and weaknesses of the current usage of customer research data within automotive NPD and what are the current sources of data used? In order to ensure that the evaluation methods investigated in this research are representative of those used by the automotive industry, an initial study with an automotive OEM was conducted. This helped to ensure that any research carried out successfully contributed towards generating new knowledge in academia and also has a real-world benefit for the automotive industry. After identifying the sources of customer research data used by the OEM, it was possible to identify opportunities to provide knowledge to improve designers and engineers perception of customers.

- **Objective 1) -** To identify knowledge which can further the current understanding of customers from existing sources of customer research data used within the automotive industry.

Research Question 2) How do the decision-making criteria used by assessors compare between market research techniques and structured evaluations? Potential psychological constructs were evaluated in Chapter 3, which could be used as a focus to examine differences between structured evaluations and market research. Understanding the decision-making criteria used by assessors in SQ evaluations for structured evaluations and market research remains unknown from the available literature and therefore provides an opportunity to carry out empirical research to generate relevant knowledge. The research question can be answered by examining the decision-making criteria used by the assessors in market research surveys and

structured evaluations for automotive SQ. The following objectives can be used to help answer the research question set:

- **Objective 2 A) -** To understand how assessors evaluate vehicle sound in structured evaluations and market research, through the use of Verbal Protocols.
- **Objective 2 B) -** To compare structured evaluations with market research in terms of decision-making criteria.

5.4. Research Design

A mixed-method research design was implemented for data collection and analysis, (Howitt and Cramer, 2005; Ridenour et al., 2008). The particular research design allowed assessor's experiences to be captured in their richest form, whilst also allowing them to be quantified into numerical values for analysis. For the data collection phases of this research, an observational research design was adopted, to understand how individuals behave during a given task (Shaughnessy et al., 2006; Madill and Gough, 2008), e.g., SQ evaluation methods.

5.4.1. Research Process

There are three stages in this research process, which are presented in Fig. 5.1:

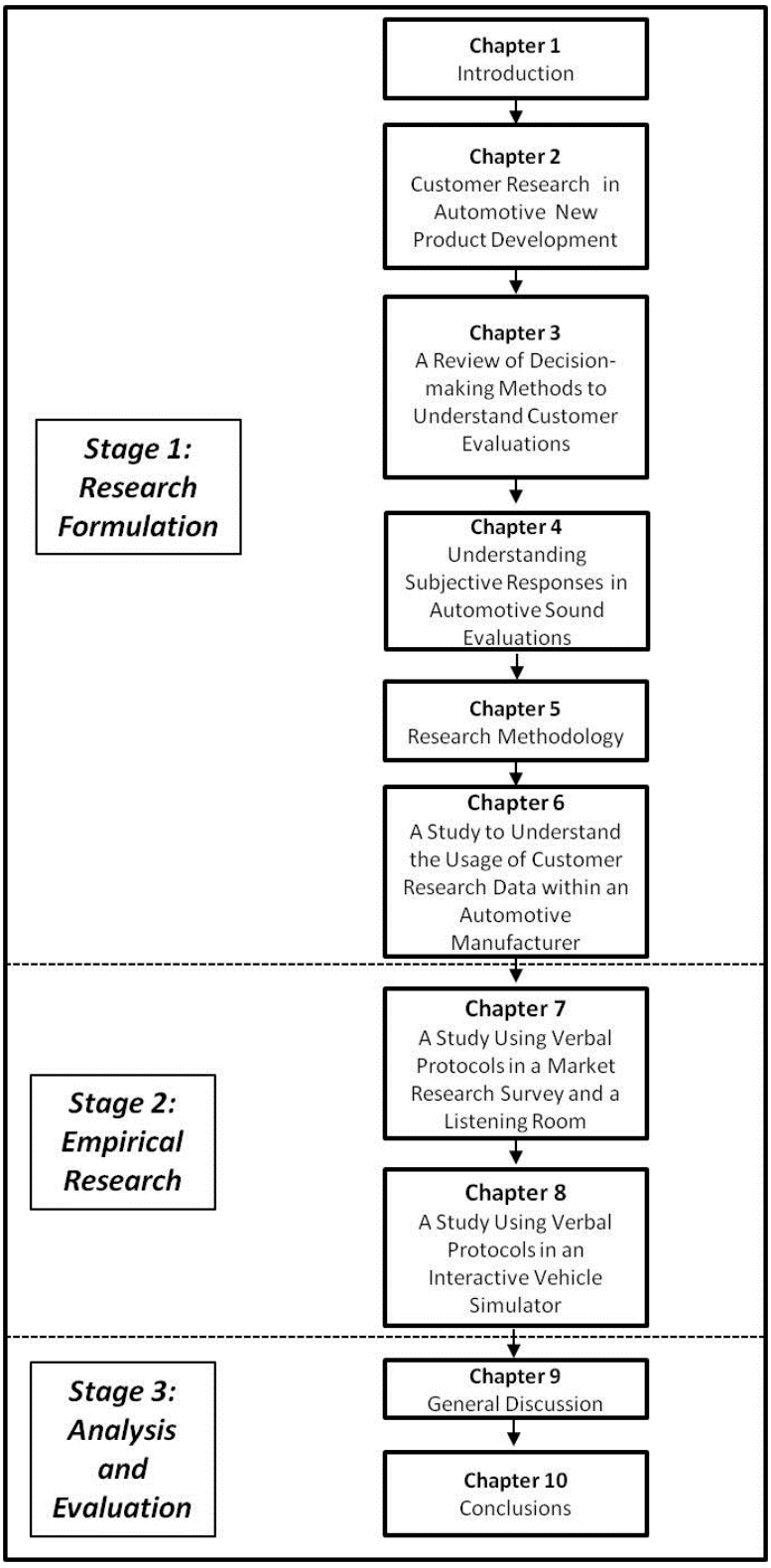


Figure 5.1: The stages of this research

Stage 1: Research Formulation

This stage examined existing research carried out to understand subjective evaluations made by customers in NPD (Chapter 2), which set the context of the research presented in this thesis. Due to the lack of literature regarding how market research surveys and structured evaluations differ in terms of evaluative criteria, understanding how assessors take part in evaluations was suggested to contribute to knowledge. Chapter 3 identified decision-making methods to understand how individuals take part in a market research and structured evaluations.

However, the literature alone was insufficient to ensure the generation of new knowledge, as automotive OEMs can conduct their own in-house research which may not be published. To understand the usage and further identify specific sources of customer research, a preliminary study was carried out involving an automotive OEM (Chapter 6). The study helped understand how automotive experts perceived customer data and provided potential directions to progress the current state of knowledge for customer research, which could be beneficial for both academia and industry. The study also helped to achieve Research Question 1.

Stage 2: Empirical Research

The empirical research in this thesis adopted a Verbal Protocol elicitation technique (Section 3.3.1) as the primary data collection method to understand the decision-making processes assessors use when taking part in structured evaluations and a market research approach. Prior to using a Verbal Protocol elicitation technique, a warm-up exercise was recommended to help assessors become accustomed to verbalising their thoughts. Ericsson and Simon (1993) recommend that practice sessions should avoid complicated and confusing instructions.

Verbal Protocols were captured in a structured evaluation set in a listening room and a market research survey, which helps to answer Research Question 2. To further investigate the decision-making criteria for behavioural influences using a more representative method for driving, Study 3 progressed the current investigation to incorporate a Verbal Protocol elicitation technique in an interactive vehicle simulator (Chapter 8).

The collected Verbal Protocols in this thesis reflect assessor's thoughts and decision-making criteria in SQ evaluations and market research. As this research was set within an applied area, i.e. the automotive industry, it was important to invite assessors who are representative of those taking part in vehicle evaluations. Therefore, owning a vehicle was a prerequisite for participating in the studies. As participants in this research evaluated SQ, participants will be referred to as assessors.

Stage 3: Analysis and Evaluations

A mixed-data analysis (Howitt and Cramer, 2005) approach was required when evaluating the decision-making criteria used by assessors as both qualitative and quantitative statistical techniques were needed to analyse the data. The first part of the analysis required the qualitative data to be analysed.

A Thematic Analysis allowed the qualitative data to be analysed. Woods (2006) describes a theme as, "*A statement of meaning that runs throughout all or most of the data*." Each theme in the data was identified and coded using qualitative data analysis software (NVivo 9). Braunt and Clarke (2006) and Guest et al. (2011) describe the steps of Thematic Analysis to include:

1. Reading transcripts.
2. Identifying themes.
3. Comparing and contrasting the content of themes.

The second part of the analysis relied on quantitative methods to assign frequencies to the categories of decision-making criteria observed. This approach is supported from researchers who have used Verbal Protocols (Ranyard and Svenson, 2011). In order to make a comparison frequencies were assigned using a Content Analysis approach (Hseih and Shannon, 2005). Inferential statistics for categorical based data were carried out, using a series statistical techniques which are outlined next to help understand the analyses in this research.

The analysis of results from the empirical research stage will follow a process illustrated in Fig. 5.2.

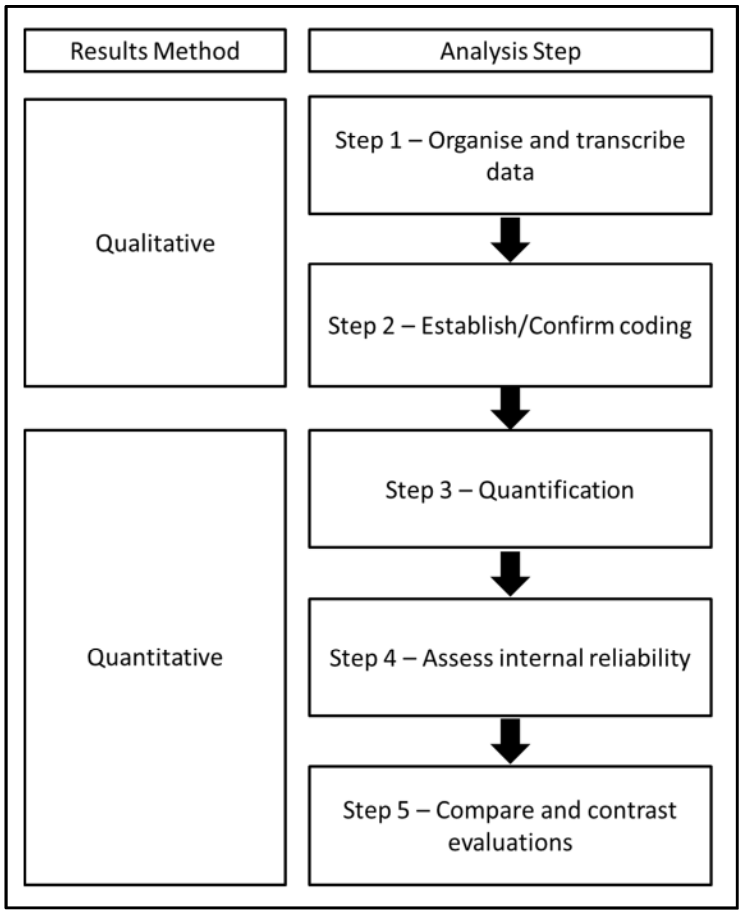


Figure 5.2: Analyses steps for evaluating data in Chapters 7 and 8

Chi-Square Tests

As the quantified Verbal Protocols are classified as categorical data, chi-square (χ^2) tests of association were carried out to provide inferential statistics to determine if a there were any associations between decision-making criteria and the customer research evaluation method.

Strength of Associations

The strength of associations between decision-making criteria and methods can also be assessed using Cramér's V for effect size or with Odds ratios. Measured as Cramér's V, effect sizes were calculated in this research to understand the strength of the chi-square association on the sample (Howell, 2004).

Howell (2004) defines Odds Ratios (OR) as, *"The frequency of occurrence of one event divided by the frequency of occurrence of another event."* ORs were used to help determine the likelihood of certain decision-making criteria to occur between methods, e.g., the likelihood of 'behavioural' scenarios to occur in a market research survey over a listening room evaluation.

Cronbach's Alpha

In order assess the internal reliability of 'powerfulness' and 'refined' measures of SQ (Jennings et al., 2010) Cronbach's Alpha (1990) were carried out. Alpha scores over 0.6 are considered as an acceptable measure of internal reliability (Götz et al., 2010).

5.5. Validity and Reliability of Data

The following sub-sections can be used as a framework outlined by Taylor (2001) to evaluate the validity of qualitative results in this thesis and will also be referred to in Chapter 9.

Recommended Use of Methods

Taylor (2001) suggests that the use of methods to obtain qualitative data should be carried out in a recommended manner to maintain validity. To ensure that the methods used in this research was carried out in a valid manner, literature which provided guidelines for using a Verbal Protocol methods was referred to during the planning of studies (Schulte-Mecklenbeck et al., 2011).

Compare with Published Research

Taylor (2001) suggests comparing findings with published research in order to assess the validity of qualitative data. In the case of this research, no academic publications were found which examined the decision-making criteria for both structured evaluations and market research. The findings from this research were compared to related studies investigating the language used in structured evaluations and pre/post-purchase studies.

Determine Usefulness and Applicability

Understanding the usefulness and applicability of the research can also provide a measure for validity using qualitative data analysis (Taylor, 2001). A preliminary study with employees and

managers from an automotive OEM (Chapter 6) can help to reveal valuable recommendations and potential future directions that can be used to better understand the data from customer research. This thesis therefore provides an initiative which addresses the insights expressed by automotive experts. Furthermore, Verbal Protocols can be applied to a range of evaluation techniques which were identified in Chapter 3.

Additional Validity via Triangulation methods

Triangulation refers to the use of different methods of data collection, which reach the same findings (Howitt and Cramer, 2005). This can be carried out using TLPs (Section 3.3.1), where assessors in the SQ evaluations could write down any evaluation criteria or thoughts without the experimenter being present.

5.6. Ethical Considerations

This research abided by the ethical guidelines provided by the University of Warwick. Prior to any data collection using assessors, each study in this thesis was assessed by an independent member of academic staff. Informed consents were collected from assessors who were made aware of any issues which may arise from the empirical research. Informed consent forms were collected before each study was carried out. Assessors were also informed that their results consisted of audio and video recordings which would be stored securely and anonymously.

5.7. Summary

The following conclusions helped to achieve the research objectives and answer the questions set in this research.

- A psychological perspective provided a novel approach to examine the differences in decision-making criteria for (i) market research based methods and (ii) structured evaluations. This provided an original contribution by examining how customers evaluate a vehicle attribute in an engineering discipline.

- A mixed-method approach for the data analysis was used to examine the Verbal Protocols. A Thematic Analysis established the criteria used by assessors. A Content Analysis allowed a quantitative comparison between customer research methods.

- Vehicle owners from the University of Warwick were selected as assessors to take part either in a market research survey, a structured evaluation in a listening room, or a structured evaluation in a vehicle simulator.

- Triangulations using TLPs provided an additional validity measure when analysing qualitative data.

- The empirical research in this thesis was conducted in accordance with ethical guidelines set by the university. All assessors were provided with information regarding each study (Appendix B and C) and informed consent forms were collected at the beginning of each empirical study.

The next chapter will present a study which examines existing issues facing customer research data used within an automotive OEM.

Chapter 6

A Study to Understand the Usage of Customer Research Data within an Automotive Manufacturer

6. A Study to Understand the Usage of Customer Research Data within an Automotive Manufacturer

6.1. Introduction

This chapter presents a study that was carried out with an automotive OEM to further understand the usage and identification of customer research data sources in automotive NPD. This study also provided direction to the research and refined the scope of this thesis.

6.2. Rationale

Chapter 2 identified a number of potential challenges facing automotive NPD which included the difficulties of customer research data being fully understood by designers and engineers. Understanding how customers evaluate vehicle attributes was another challenge identified from the literature, which has the potential to be further investigated through a series of psychological methods investigating customer decision-making (Chapter 3).

As automotive OEMs have the capacity to carry out in-house research to further understand customers, it was important to understand if any existing solutions had been carried out by OEM experts working with customer research data in the automotive industry. Understanding the current usage of customer research data within an OEM can help to identify strengths and weaknesses of the available sources, as well as to help understand what is currently being done to overcome customer data issues. This study could be used to confirm potential gaps found in the literature (Chapter 2) from an industrial perspective and therefore, help to ensure that the knowledge created from this research can be of a significant contribution to academia and provide value to industry. Berman (1990) establishes one of the benefits of academic – industrial collaborations to increase future industrial research and aid with the transfer of academic knowledge towards relevant concerns in industry. As a result, studies of such nature could help provide a complete picture needed for successful product development (Song et al., 1997).

6.2.1. Study Aim

The study will help to answer **Research Question (1)** in this thesis which is to understand - What are the strengths and weaknesses of the current usage of customer research data is used within automotive NPD and what are the current sources of data used? The study will also aim to achieve **Research Objective (1)** which is - To identify knowledge which can further the current understanding of customers from existing sources of customer research data used within the automotive industry.

6.3. Method

This study was carried out as workshop held at the University of Warwick with managers from an automotive OEM in an initiative to help improve the existing understanding of customer data. All materials used in the study are presented in Appendix A.

6.3.1. Attendees

As it is automotive management who make decisions on behalf of customers in NPD (Ludvigsen, 1996), this study invited 15 automotive OEM employees to shed light on customer research issues. Employees which included a selection of managers, team leaders and directors attended. The attendees had expertise in the following areas of vehicle development:

- Quality
- Product Strategy
- Design
- Market Research
- Service Operations

Three additional members of the Experiential Engineering group in the WMG department at the University of Warwick adopted roles as facilitators to ensure that the attendees remained focused on the topic. Attendees were pre-assigned into three groups for the purpose of managing and facilitating the study.

6.3.2. Design

In order to achieve the aims and objectives, this study included four sessions which used open-ended designed questions to allow the attendees to freely respond which could provide a further insight of the issues facing automotive OEMs regarding customer research data. The sessions included were:

- **Session 1) Wouldn't it be nice if we knew [...] from real customer data? -** This session was designed to identify as many possible areas/ideas/concepts that the attendees felt could enhance perceptions of customers from data. As this was the first session in the study, it was intended to help assessors become comfortable in sharing their opinions.
- **Session 2) What data is currently available to us? -** This session aimed to identify the sources of customer data currently available to an automotive OEM. This session highlighted specific sources of data which can be further researched in this thesis to allow a comparison between market research sources and structured evaluations.
- **Session 3) Label Grouping -** This session allowed attendees to cluster the written responses. Clustered responses, could help identify the themes and issues facing an automotive OEM.
- **Session 4) What are the next steps?** - The final session was designed to conclude the study and sum up any important aspects identified during the study. It was decided to structure this session to ask attendees, A) what data was still needed, B) how to make better use of existing data and C) to answer any questions before summarising and concluding the study.

Using Affinity Diagramming to Capture Responses

Responses were collected using an Affinity Diagramming method (Kawakita, 1982; Hanington and Martin, 2012). Affinity Diagramming allows individuals to respond to a number of questions by writing onto sticky note paper. The responses can then be used for Label Grouping.

Label Grouping includes the clustering and categorisation of responses into themes. An example of Label Making and Label Grouping is shown in Fig 6.1.

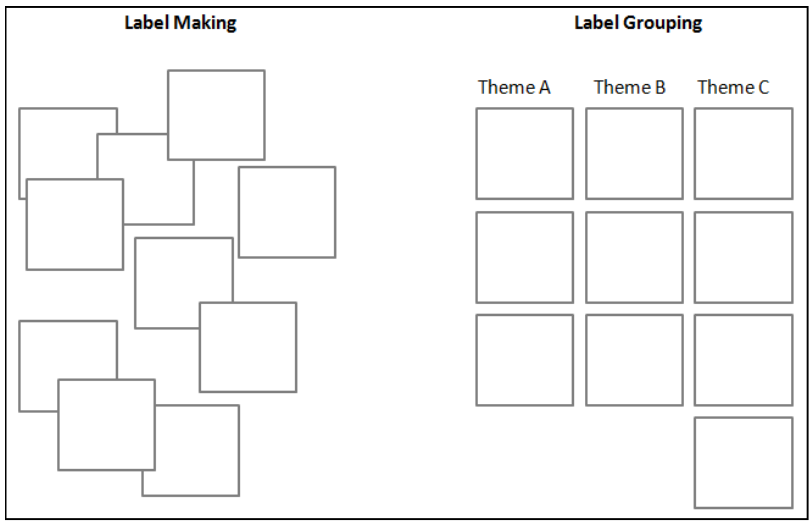


Figure 6.1: Label Making and Label Grouping in Affinity Diagramming

Scupin (1997) describes each of the steps involved in the Affinity Diagramming method as:

1. Label Making (writing responses to question per session).
2. Label Grouping (clustering responses for each question).
3. Verbal or written explanation (discussion and summary of responses).

One of the benefits for using Affinity Diagramming is that it allows all attendees to have an equal opportunity to respond to questions and includes no restrictions on the number of responses that attendees can provide (Hanington and Martin, 2012). This allows anyone who has a number of ideas to contribute without influencing others.

6.3.3. Procedure

Attendees were presented with introductory PowerPoint slides (Appendix A). During which, it was stressed that no restrictions would be placed on the number of responses that each attendee could make. The role of the facilitator and observer were defined. Attendees were reminded that the observer and facilitators were present to ensure that everyone focussed on the questions set and to provide assistance, if needed.

For each session, a question or a specific exercise was presented via PowerPoint slides and allowed attendees to write their responses on sticky note paper. Once these were written, they would be collected by the observer and facilitators. During the label grouping phase, the sticky note paper were distributed evenly across surfaces to allow attendees to group them. Figure 6.2 presents a flow diagram of the order in which sessions were carried out.

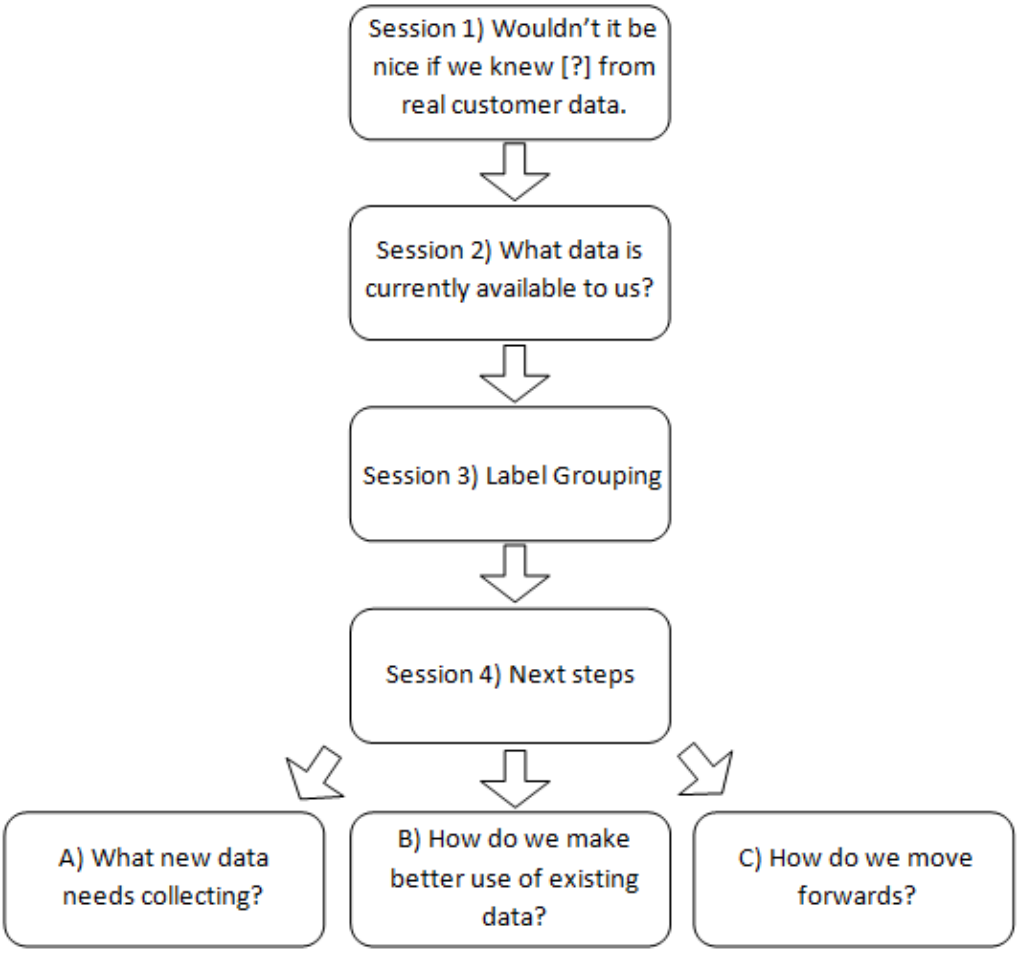


Figure 6.2: The order in which the sessions were carried out

6.4. Results

In total 300 written responses were collected. A Content Analysis (Kassarjian, 1977, Hsieh and Shannon, 2005) was also carried out in order to determine the importance of categorised responses through ranking the most populated categories. The results were categorised to help understand the following issues

1. What new data can provide an in-depth understanding of customers?
2. What is the data is currently available to the OEM?
3. What are the next steps needed to provide value to this research?

6.4.1. Identifying New Data Which Can Provide an In-depth Understanding of Customers

This session aimed to identify knowledge which can enhance an automotive OEMs perception of customers. Responses from attendees were ranked by the frequencies received. Attendees had the opportunity to describe the categorisation process, which are summarised in this thesis with presented in Table 6.1.

Table 6.1: Insights which can enhance the OEMs perception of customers in response to Question 1) Wouldn't it be nice if we knew […] from customers

Theme	Comment Frequency	Description	Wouldn't it be nice if we knew […]?
Understand Customer Usage and Lifestyle	26	The responses collected under this category identified the need to gain more knowledge about the behaviour and lifestyle of vehicle owners. Lifestyle comments consisted of elements such as customer purchasing behaviour and how vehicles related to other purchases. Behavioural comments included the need to identify usage of the vehicle, the interaction with other passengers and identifying the best driving experiences. Cultural differences also attracted the need for further insights. The psychology of how features are used was also suggested, showing that an understanding how customers think about features can also be of interest.	Who they want to be with, in the car?
			How does the customer use our (or their) vehicles?
			Customers – U.S Vs. Europe Vs. Asia.
			On a wet sunny day, I could see clearly through the front window without any glare.
			Relative importance of car amongst other purchases in life.
			Psychology use of features.
Feature/ Importance	17	Practical usage of features and attributes is a common theme in this category. Understanding how customers use features and what customers may like from future designed features was identified. Interestingly, one particular insight requests the need for information for understanding what may have been missed from the design team is an important insight to achieve.	The frequency of use of each feature.
			Those items which are a real delight/surprise.
			If customers like our quirky ideas?
			What did the design team miss?
			What new technologies are most useful to the customer?
			What the customer wanted?
			Would a lack of feature stop a customer buying a vehicle?
Customer – Speak	13	The insights categorised for this theme signify the interest for understanding and speaking the same language as the customer. The comments indicate the interest to understand customer issues in their expressed views.	What really matters to them?
			What are the key customer issues as expressed in their own words?
			Passenger feedback about their likes / dislikes.
			Their idea of the best non-automotive products they have seen?
			Understood my driving style and adapted the car theme to it.
			What would they redesign in the car?
			What the customer said about a particular feature/fault?
			Accurate verbatim on TGWs of what the customer said?

Theme	Comment Frequency	Description	Wouldn't it be nice if we knew […]?
Buy/No-Buy	9	This category captured responses towards understanding the reasons why customers purchase a particular brand of vehicle.	Why did they purchase X instead of Y?
			What is preventing them from repurchasing?
			Key reasons why people rejected buying our cars.
			What were the real reasons for making their vehicle purchase?
Competitor Information	8	The responses from attendees identify a need to understand more competitors. Competition can pose a strong threat within the automotive industry, which can explain the need to further understand how customers evaluate competitor products. Interestingly, an insight towards understanding the subconscious factors in how customers compare their vehicle was identified.	What they like about competitor vehicles?
			Comparison with other luxury brands.
			Their idea of the best features from all the cars on the market.
			How customers compare cars from previous experiences?
			Subconsciously - What are they comparing our features and functionality to?
Trade-offs	8	The comments collected for this category focussed towards understanding how customers make choices in terms of features, environmental impact and cost.	How willing are they to make conscious trade-offs, e.g., Design – Package Product Quality – Feature?
			If environmental issues are the top of their concerns or is it more basic like cost of motoring?
			Attributes, e.g., Sound. Relative importance of parts of drive cycle.
			What to prioritise from a satisfaction and cost perspective?
			If they had to make choices, e.g., Attribute Vs. trim, what would they do?
			What are the customers priority of various elements of the car?

Theme	Comment Frequency	Description	Wouldn't it be nice if we knew […]?
Sales Experience	6	The comments in this category highlight the need to understand the relationship between the customer and the dealerships. This can be important, as the Dealership is the first point of contact with the automotive company.	What disappointments/frustrations they have with dealers?
			What they think of sales people?
			What, in their opinion, makes outstanding customer service?
			When do they feel their car needs replacing?
			How to persuade them to buy?
			What is the experience of the 2^{nd}/3^{rd} + 4^{th}.... owner?
Sources/ Surveys	6	Attendees provided comments in this category related to how much customers actually rely on and access information from JD Power and other customer surveys.	How much do they rely on consumer surveys, e.g., JD power in making their purchase decisions?
			How do they choose between cars/brands. Where do they access information?
			How they react about the car when they were in it situation?
			Which of our customers never respond to surveys? How do we talk to them?

6.4.2. Identifying What Data is Currently Available?

The following sources of customer data were identified to be used in NPD and are reported in order of most populated responses, frequencies of comments received are provided in brackets:

- **Internal Data –** These included clinics and internal reports from the Vehicle Assessments Group (VAG). Insights from employees as well as panels were categorised within internal data sources (20).
- **Market Research –** This category highlighted a range of J. D Power surveys which are used in NPD. The surveys ranged from capturing initial quality concerns to understanding both positive and negative aspects of the vehicle (20).
- **Agencies –** Sources of data included the Roadside Assistance Data, Industry conferences and Engineering/Research Surveys. Universities and academic institutes were mentioned here (16).
- **Media –** This included responses such as press reviews and car reviews (10).
- **Benchmarking/Teardown –** This category shares similar concepts to competitor data that is available. An example of this is with comments such as competitor analysis, competitor data: metrics (current) – intelligence (future) (10).
- **Hard Data –** Responses included sales figures and objective based data. There are various sources mentioned here such as Total Industry Volume (TIV) data, Sales Global Insights, Vehicle Sales Data and companies providing pricing info. Transport statistics are also mentioned here along with sales figures (8).
- **Word of Mouth –** Responses included knowledge from individuals and personal recommendations (8).
- **Internet –** Responses included internet websites, blogs, social networking and video broadcasting channels such as YouTube (7).

6.4.3. What are the Next Steps?

Attendees in the final session were given an opportunity to answer the following questions, which were analysed using a Thematic Analysis approach (Chapter 5):

A. What data still needed to be collected?

B. How to make better use of sources?

C. How to move forwards?

Question A) What New Data Needs collecting?

Responses for this question consisted of potential new data that the attendees expressed that needs to be collected. Table 6.2 presents the suggestions and insights expressed by attendees which have been summarised and also ranked from the most received responses in descending order.

Table 6.2: Data which is still needs collecting

Theme	Comment Frequency	Description	Data which still needs to be collected
Customer Decision-Making	9	The responses can be categorised towards understanding how customers make their decisions regarding vehicles.	Implicit opinions and spontaneous reactions from real customers.
			More informative data to get an understanding of what really gives a delight or/and surprise to our customers.
			…No good asking about technology solutions but understanding their problems/frustrations could be useful…
			More info on what exceeds owner expectations.
Customer Lifestyle	6	Attendees clustered responses which noted the need to capture more information on customer lifestyle and understanding customer experiences.	Need to collect more "soft" data on customers/rejecters and make data actionable.
			Non-automotive – Lifestyle other product data.
			Confirmation of our future product strategy and plans by tapping into customer lifestyle, spoken and unspoken needs/wants.
			360^{o} View of customer ownership experience.
Driver Behaviour	4	An interest in understanding how customers drove the vehicles was found. A suggestion to create user profiles of different customers with driving habits was suggested.	Develop a greater understanding of Driver, Customer behaviour – 1 – Journey profiles and usage.
			Need a better understanding of customer behaviour regarding how they consider body styles, size segments (D,E,F etc.) power trains, features. The question is, how free are we to defy convention in defining a new product proposition.
			Develop a greater understanding of driver, customer behaviour – 2, Driver model for i) CO2 ii) Appraisal.
			Define/Segment Customer, Driving Habits and demographics. Create "user profile".
Customer Trends	3	Responses here included the interest to examine the issues which would face customers in the future.	What would the customer like on his car in the future – 3 years, 5 years → longer.
			Future benchmarking or future competitor info.

Question B) How Do We Make Better Use of Existing Data?

Responses for this question were categorised into the following themes considering existing data:

- **Better Structure –** The layout and structure of the data were suggested for improving the current usage of data for the automotive OEM.
- **Corporate strategies –** A number of responses were specific to the automotive OEM.
- **Data Interpretation –** Attendees in the workshop identified a need for better data interpretation was needed from initiatives outlined in Session 2 (Section 6.4.2).

Question C) How do we move forwards?

This session summarised the responses from Sessions 1, 2 and 4, and drew the study to a close. This session was also used to collect any feedback from attendees.

6.5. Discussion

This study set out to identify the sources of customer data used in automotive NPD (and to ensure that this research selected representative methods used by the automotive industry to further investigate in this thesis. Prior to this study, a series of challenges were identified from the literature which could face an automotive OEM regarding the involvement of customers into the NPD process (Chapter 2).This study allowed an automotive OEM to raise issues regarding the usage of customer research data in general and did not focus on a particular approach. This allowed many issues facing customer data to be raised. It was also important to carry out this study in order to understand if any existing initiatives had been carried out by an automotive OEM when investigating structured evaluations and market research. First the discussion will examine insights expressed by the automotive employees which could help to further understand customers.

How to Further Understand Customers?

Attendees initially expressed interests to further understand driver behaviour and customer lifestyles as it was believed that these insights would provide an enhanced perception of customers, which was currently missing from available data sources. Additional areas of interest included to further understand the impact of competitor products on customers' understanding of vehicle attributes and to understand customer language to describe attributes.

The expressed areas of interest could potentially provide deeper insights of customers however, practicality and feasibility were not considered during the initial session. Therefore, not all of the responses may be viable or practical. Additionally, during the opening session of the study, attendees may have raised interests and concepts without being aware of existing data sources which may provide the expressed interests. Interestingly, the responses related to surveys did not receive as much attention as the other themes identified in Session 1, which is surprising considering it is one of the methods to capture the opinions of customers.

Available Customer Data

When examining the available data sources, internal data sources received the highest frequency of responses. The second most populated set of responses were identified as market research data. This suggests that the attendees could be familiar with market research sources through their usage and are also aware of the importance of achieving favourable market research data. After identifying the sources of data available, attendees may have been able to better link the sources identified in Session 1. Attendees were therefore given another opportunity in Session 4 to identify any new data which they felt needed to be collected.

Data Which Could Provide Further Value to OEMs

The attendees were given another opportunity to express insights from customers Another difference in Session 4 compared to the 1st session was that attendees could suggest new types of data which could enhance their perceptions of customers without adding to the overabundance of data sources which were found in Session 2. Therefore the responses

observed in Table 6.2 are suggested to be more practical and viable to further research in this thesis. Responses were categorised into the following groups:

- **Customer Decision-Making** – Responses were categorised as decision-making as insights expressed by the OEM attendees showed the need to identify and understand the implicit opinions and spontaneous reactions from real customers. Examining customer decision-making could therefore provide designers and engineers with enhanced customer perceptions data. Other responses which were categorised here also shared the theme of understanding beyond the responses captured, e.g., to get an insight of customers in their own language and to further understand what would exceed owner expectations. One practical and feasible way to achieve these insights is by using Verbal Protocols to examine the decision-making processes of customers (Chapter 3).

- **Customer Lifestyle** – Understanding the customer lifestyle was regarded to be important to further enhance the understanding of customer data. It was a theme identified broadly in Session 1 and again in the final sessions. However, the responses in this category were very broad and did not provide a practical way to further understand customer lifestyle data and needs further research to define aspects of customers lifestyle which would add value to understanding customers which could be carried out through ethnographic approaches.

- **Driving Behaviour** – Driving behaviour in this broader category relates to understanding more about how the vehicle is being used with a particular focus on how customers drive vehicles and use features.

- **Customer Trends** – As vehicles take anywhere between 24 and 36 months to plan and manufacture (Spall and Ahn, 2000), the attendees felt that understanding customer trends would be beneficial to examine.

Customer Orientation

The results from this study share characteristics with Customer-Orientation studies from the available literature. Customer-Orientation is the process of directing an organisation or employees focus of attention towards customer related issues and understanding customer contributions towards a business (Lengnick-Hall, 1996). This orientation can be delivered through Customer Relationship Management (CRM) (Chen and Popvich, 2003) initiatives which Baran et al. (2008) describe are based on understanding:

i) The customer's interaction with the company.

ii) The human factor involved and organisational changes needed.

iii) The technology needed for the change.

The findings from this chapter add to the existing understanding by identifying the important aspects of customers which are important to organisations who wish to become focussed on customers, e.g., understanding implicit opinions, customer lifestyle driver behaviour and customer trends.

The results in this study create a further discussion where Meyer and Schwager (2007) suggest decision-makers within an organisation may believe customer satisfaction is sufficient to understand the customer but may fail to appreciate that customer experience of the product should also be investigated. Having identified areas that are of interest to the automotive OEM, it is suggested that investigating the decision-making criteria customers use can provide answers to many of the insights which were raised.

Comments on Data Collection Method

The study adopted the Affinity Diagramming method in order to encourage all attendees to make a contribution and to feel comfortable with sharing their opinions as it may be difficult for those within an industry to collaborate with other institutions particularly with sharing company information. This can be advantageous and reduce the role of experimenter bias in the study. One of the drawbacks which come with the richness of data captured is the intensive process of analysis and degree of interpretations which can be drawn from the results and through

qualitative data analysis transcriptions in general. Chapter 5 presented a framework to maintain the validity and reliability of interpretations derived from qualitative data.

6.6. Summary

This study has provided a perspective from industry which confirmed that existing customer research needs to be further understood in order to provide an in-depth perspective of customers. This could aid data interpretation for experts working in automotive OEM management.

This study identified practical insights that could further enhance the automotive OEMs perspectives of their customers through existing vehicle evaluations. It also confirmed the initial need to understand the decision-making processes customers experience in evaluations which could be achieved through a psychological perspective. This potentially could provide a solution in generating an in-depth understanding of the information customers use to evaluate vehicle features and to determine the influence of methods on the vehicle attribute evaluation procedure.

Sources of customer data available to an automotive OEM were also identified in this study. This study identified potential methods that could be used as the basis for identifying decision-making criteria customers experience in evaluation settings which can be carried out in a representative manner. The study has indicated the need for insights beyond direct quantitative measurements, particularly when interpreting the subjectivity of assessor's responses to SQ.

Understanding the decision-making criteria customers experience in each of the evaluations can provide designers and engineers in NPD with answers to many of the expressed insights identified in this study. Additionally, the need for an improved data structure to allow teams within the OEM to be aware of the sources of data to allow easier access was identified. Furthermore, a literature review of vehicle SQ in Chapter 4, identified that assessing customer decision-making in SQ subjective evaluations provides an opportunity to make a significant contribution to knowledge by comparing structured evaluations with market research approaches.

Chapter 7
A Study Using Verbal Protocols in a Market Research Survey and a Listening Room Structured Evaluation

7. A Study Using Verbal Protocols in a Market Research Survey and a Listening Room Structured Evaluation

7.1. Introduction

This chapter presents a study which used Verbal Protocols to understand the decision-making criteria used by assessors when evaluating automotive SQ. The study provides an insight into the types of decision-making criteria used by assessors in a market research survey and a listening room evaluation.

7.1.1. Rationale

SQ can provide drivers with feedback of how a vehicle is performing. SQ can also be engineered to add a positive driving experience (Cerrato, 2009) that can enhance customer satisfaction (Dunne, 2003). Therefore, it is important that the methods which capture SQ responses are fully understood in order to set engineering targets which satisfy customer needs.

Knowledge of how assessors evaluate vehicle sound in a market research survey remains untapped. As OEMs need to better understand customer needs, focussing on the decision-making criteria vehicle owners use earlier in NPD provides the potential to improve evaluation responses and future vehicles which further meet customer needs.

7.1.2. Study Aim

This study aims to identify the decision-making criteria used by assessors when they evaluate SQ questions in (i) a market research survey and (ii) a listening room evaluation. The current study aimed to answer the following research question and objective:

Research Question 2) How does the decision-making criteria used by assessors compare between market research techniques and structured evaluations?

- **Objective 2 A) -** To understand how assessors evaluate vehicle sound in structured evaluations and market research, through the use of Verbal Protocols.

Identifying the decision-making criteria used by assessors for each of the methods can allow a comparison between structured evaluations and a market research survey which will help achieve Research Objective 2 B.

7.2. Method

The study was conducted in the 'Product Perception Laboratory' at the University of Warwick which accommodates a listening room and provided the setting for this study.

Assessors

Assessors were recruited from a sample of vehicle owners who volunteered in response to an advertisement distributed across the University of Warwick (Appendix B). Thirty-one non-experts assessors took part in this study, 20 of which were male and 11 were female. The average age of an assessor was 33 (Range: 24-55). On average, assessors had held their driving license for 14 years (Range: 5-36). Assessors were randomly assigned to take part in either a listening room structured evaluation or a market research survey.

Design

A between-subjects design was utilised with two independent groups. The two groups included a market research survey (Group A) and a structured evaluation in a listening room (Group B). This study was designed to allow assessors to experience the methods in a manner representative to that used by the automotive industry. The question wording in each of the groups was kept consistent to allow a comparison of the decision-making criteria captured for each of the evaluations.

Equipment and Setting

To ensure that the environment for both evaluations remained constant, a listening room was used, which was arranged using existing guidelines (Otto, 1999). A portable sound recorder was used to record the verbalised decisions from assessors. For the structured evaluation, a touch-screen user-interface was used to display a Microsoft Excel template to capture the responses (Appendix B). The sound stimulus was presented to assessors was reproduced through a pair of Stax SR-303 electrostatic open headphones. The arrangement of the listening room can be seen in Appendix B.

Materials

Market research survey (Group A)

The market research survey was designed using an existing automotive survey with representative scales, layout and questions to capture customer responses towards vehicle attributes. The survey used is available in Appendix B. Sections 1 and 2 collected the details of the vehicle and the reasoning behind assessor's vehicle choice. Sections 3 to 5, focussed on capturing assessor's responses towards vehicle attributes for (i) the engine, (ii) transmission, (iii) vehicle exterior and (iv) vehicle interior. Each SQ question was placed within each of the mentioned vehicle areas. Section 6 accommodated the specific SQ questions from the listening room evaluation. Lastly, Section 7 collected the assessor's demographical data. The survey used 10-point Likert scale for responses. In order to remain representative of the methods used by the automotive OEM, scales and anchor points matched existing tools from the industry.

Listening Room Structured Evaluation (Group B)

The structured evaluation setting used a Microsoft Excel template which was based on previous SQ trials in the Product Perception Laboratory to capture assessors responses. The template included six SQ questions and replicated the semantics used in the market research survey which uses a 10-point semantic differential instrument (Chapter 4). The sounds presented to assessors consisted of a WOT sound from a premium saloon which have been previously used for evaluations. No additional stimulus was presented. The excel template used are available in Appendix B for reference.

7.2.1. Procedure

The first task assessors were given was to practice verbalising their thoughts by completing mathematical problems aloud. All assessors were presented with a mathematical problem sheet (Appendix B). Once assessors were comfortable, the following procedures were carried for each setting:

A. **(i)** Assessors taking part in a market research setting were presented with the survey and were asked to verbalise any decision-making and thoughts that they experienced, while answering each of the questions. Once assessors had completed Sections 2 to 5, the demographic section was completed without verbalisations.

A. **(ii)** Assessors in structured evaluation setting had to navigate through an Excel interface, where they would have to listen to the interior sound of vehicle and subsequently rate the stimulus, while verbalising their thoughts and decisions.

B. If assessors encountered difficulties in verbalising their thoughts, scripted prompts were used to help the assessor, to focus on their decision-making (Appendix B).

C. For both settings, assessors took part in a TLP exercise, which asked each assessor to list any thoughts and decision-making criteria towards the questions in the evaluations. This was conducted without the experimenter being present and concluded the study.

7.3. Results

Verbal Protocols recorded from Group A (market research survey) and Group B (listening room) are presented in this section. Figure 7.1 presents the methodology adopted to analyse the results (Chapter 5) with specific actions to analyse the results. Reporting qualitative data can involve a discursive element when presenting the results, however efforts will be made to discuss results further in Section 7.4.

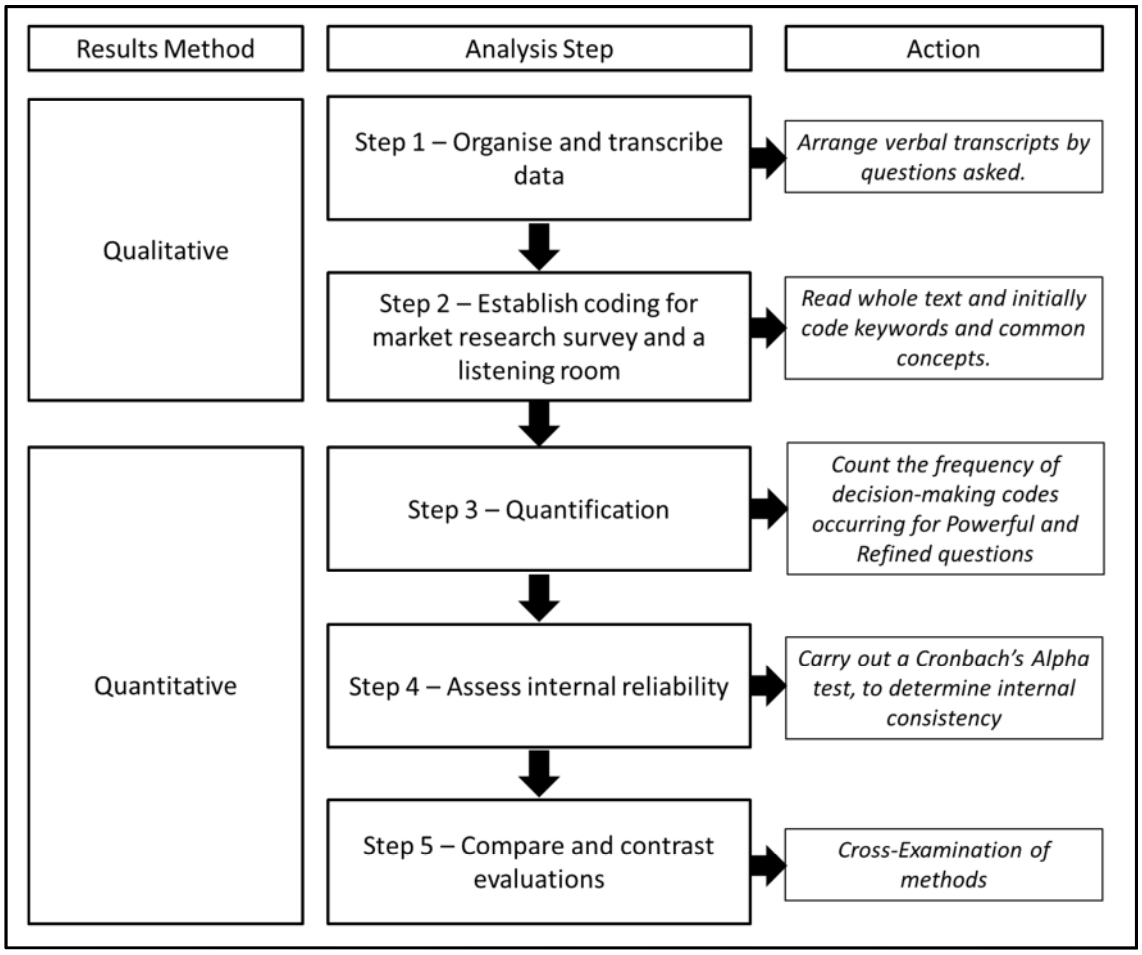


Figure 7.1: Analysis of results process

7.3.1. Qualitative Analysis

Step 1 – Organise Data

Transcribed responses were grouped into 'powerful' and 'refined' using qualitative data software NVivo 9, developed by QSR International.

Step 2 – Establish Coding

The transcripts were coded using a Thematic Analysis approach (Chapter 5). A framework was constructed to establish the coding framework which is used to help code the transcripts (Appendix B). Sub-themes were established in the framework and broader themes were interpreted from both listening test and market research transcripts. Having analysed transcripts from structured evaluations and market research settings, four emerging types of criteria were observed which showed overlap between the broader themes identified in the two settings. The transcripts from market research and structured evaluations were coded using the framework summarised in Table 7.1.

Table 7.1: Summary of the decision-making framework compiled from a market research survey and a listening room evaluation

Decision-Making Criteria	Definitions	Example
Behaviour	Action, Usage or self-reported behaviour	Setting off from Traffic Lights
Comparisons	Sounds experienced or similar sounds.	Previously owned car
Expectations	Assumptions of vehicle. e.g., Vehicle Class	Sports/Premium
Sound Stimulus	Semantics describing the stimulus	Loud, Quiet

Market Research Survey

The following section outlines the codes in detail for a market research survey. Table 7.2 presents a transcript extracts and a description of the theme for powerful based questions. The same format is carried out for refined questions and is presented in Appendix B.

Table 7.2: The themes identified when assessors evaluated SQ in a market research survey for powerfulness questions

Theme	Description of theme	Transcript Extract
Expectations	Perceived expectations were based on assessor's impressions of vehicles which were not specified in evaluations but assessors had an impression of the type of vehicle. This included vehicle classes. Verbalisations were also directed to power-train.	*"Need to understand that it is not a premium vehicle."*
		"It's not like listening to a true sports car."
		"It's noisy but it doesn't sound pleasant like a sports car."
		"Not the sound you would get from a petrol."
		"Six cylinder engines sound a lot better in a performance vehicle, in a premium prestige car, so it doesn't really with the overall image."
Comparisons	Transcripts included comparisons with the sound focus question which were used. Many assessors in the survey made comparisons to previously owned or family vehicles.	*"My mum had a car that's much quieter than mine."*
		"I would probably compare it to other cars, other cars around me I guess."
Attribute (Sound)	Individuals verbalised decisions which elaborated on the sound attribute were listed here. Assessors elaborated on the properties of the attribute either through the semantics provided in the survey question or through their own vocabulary.	*"It sounds loud, louder than it would do normally... So the character of the sound, I would say it's loud, I quite like that."*
		"There is nothing offensive there but it doesn't sound aggressive."
		"It's not too noisy it's not quiet, probably give it a five again."
		"it does sound kind of strained."
Behaviour	Codes in this category reflected assessors picturing themselves in a number of behavioural scenarios to base their decisions on the sound of the vehicle.	*"Now I'm thinking about coming off from a traffic light as well and starting my journey."*
		"I'm just thinking of my experience of driving it really, just pulling away from a roundabout or wherever, thinking about imagining myself behind the wheel."
		"Usually when I overtake you get that really good like strong sound of an engine."
		"Very nice when you put the window down.....Driving through empty long road, put your window down and you accelerate which makes you forget how much you paid for the car!"
		"I think the same thing that maybe , probably a bigger driving cycle, I think I imagined because it says from a stop, thinking traffic lights, rapid acceleration now I think I'm thinking about a country lane where I would hear the engine more because I am trying to drive faster."

Listening Room

Table 7.3 presents the codes and transcript extracts which were observed in a listening room evaluation for the 'powerfulness' measure. A sample of the refinement transcripts is presented in Appendix B.

Table 7.3: The themes identified when assessors evaluated SQ in a Listening Room for powerfulness questions

Theme	Description of theme	Transcript Extract
Expectations	While assessors were responding to vehicle sound in a listening test evaluation, additional information was not given to assessors. These codes represented expectations such as considering the vehicle segment, e.g., sports/premium.	*"Assuming this is a performance car."*
		"I'd expect this perception throughout its acceleration."
		"I find that difficult unless I was driving a high performance car."
		"It's probably a more premium vehicle that we are thinking about."
Comparisons	While assessors were responding to listening test environments, some of the responses comprised of comparison based comments towards other experienced sounds and other vehicles. Assessors also made comparisons to previous trials within the same experiment.	*"I've heard Porsche doing similar acceleration, it sounds quite similar to that."*
		"You can hear the car going through the gears, but that one doesn't."
		"It doesn't sound like my car."
		"It didn't sound as powerful as the practice trial."
		"It sounded like it could have an underlying problem, I've had quite old vehicles and they tend to have a nasty rumble underneath them and it sounded like it could have that sort of rumble."
		"To start with it sounded like the old sound."
		"It sounds like a 6 pot maybe it sounds powerful but as I said on the previous comment for the last sound."
Attribute (Sound)	Assessors in Listening Test environment also used semantics from the scales presented and focussed their comments on the sounds presented. Assessors also used their own vocabulary to describe the sounds presented.	*"I like the build up at the beginning the high revs, then it sort of gets a bit boring at the end."*
		"It starts off by accelerating quite hard which is nice, then it tails off which is disappointing."
		"A little bit rattly."
		"I like that noise. Difficult to rate it in terms (the scales) put it around somewhere around six."
Behaviour	These included scenarios and behavioural components when evaluating the sound presented.	*"It's as almost as if they haven't got their foot fully on the pedal."*
		"You can hear car going through the gears...it's more like a car going down a quiet road."
		"Sounded like it was going quite fast."

Thought Listing Protocols

A TLP exercise was carried out which requested assessors to list any thoughts in relation to the powerful and refined measures in the evaluation. TLPs were used to validate the coding in Table. 7.1 which was used for coding the transcripts in this thesis. The results from the TLP exercise are presented in Table 7.4.

Table 7.4: Summary of the TLPs captured for both listening test and market research survey

Theme	Transcript Extract
Expectations	*Cars like Bentley/ Rolls Royce come to mind*
	Does not inspire thoughts of racing drivers but of classy cars such as Audi
	I would expect different things from sports cars to premium vehicles
	Age of the vehicle
	Inferences of overall performance
Comparisons	*Does it sound like my car?*
	I think about the sound of my own car
	based on previous experience of powerful cars
	based on previous sounds presented in evaluation
	Other vehicles
Attribute (Sound)	*Low volume*
	Sporty
	Loud/loudness
	Exciting/Powerful
Behaviour	*Can I hear the car next to me @ Idle @ traffic lights?*
	Pleasant journey if quiet
	Slip Road, Green Traffic light
	Picture myself driving locally
	How the car accelerates

7.3.2. Quantitative Analysis

Step 3 - Quantification

The frequency of codes were carried out with a Content Analysis approach (Chapter 5). Table 7.5 presents the frequency of codes for powerful and refined questions from the evaluation settings.

Table 7.5: Frequencies of decision-making codes in a market research survey (MR) and in a listening room (LR) for assessing powerful and refined based questions

Measure	Setting	Behaviour	Comparisons	Attribute	Expectations	Total Codes
Powerful	MR	22	12	32	20	86
	LR	9	19	36	10	74
Refined	MR	25	12	30	11	78
	LR	14	21	28	15	78

The frequency of decision-making criteria codes for behaviour was found to be greater in a market research setting than a listening room evaluation. This was consistent for both powerful and refined measures. Comparison based decision-making also followed a trend where greater frequency of comparison codes were found for the listening room evaluation in contrast to the market research evaluation. Decision-making codes which focussed on the sound attribute remained similar on observation between the evaluation settings. Expectation criteria also differed but the relationship was not consistent between the evaluation settings. An inferential analysis is required to determine if there is an association between the frequencies of behavioural criteria and evaluation method (Step 5).

Step 4: Assess Internal Reliability of Powerful and Refined measures.

To determine if the powerful and refined measures are internally reliable, the quantitative responses were assessed with Cronbach's Alpha measures (Table 7.6). Alpha scores over 0.6 are considered as an acceptable measure of internal reliability (Götz et al., 2010).

Table 7.6: Internal reliability scores for of powerful and quietness measures in a market research survey

Setting	Measure	Question	Alpha
Market research survey	Powerful	JDP Acceleration CQI Acceleration Powerful/Weak	0.88
	Refined	JDP Interior Quietness CQI Interior Quietness Refined/Coarse	0.91
Listening room	Powerful	JDP Acceleration CQI Acceleration Powerful/Weak	0.72
	Refined	JDP Interior Quietness CQI Interior Quietness Refined/Coarse	0.73

Step 5: Comparisons between market research and structured evaluations

A chi-square test of association was carried out between behavioural and comparison based decision-making criteria and the methods. The following hypotheses were formulated to interpret the results of the chi-square test.

- *Null Hypothesis (H_o) – There is no association between the usage of behavioural scenarios used as decision-making criteria and the evaluation method.*
- *Alternate Hypothesis (H_a) – There is an association between the usage of behavioural scenarios used as decision-making criteria and the evaluation method.*

The results of the test for association are presented in Table 7.7. Values exceeding 3.84 provide evidence to reject the null hypothesis and to accept the alternate hypothesis.

Table 7.7: Chi-square (χ^2) values for examining behavioural frequencies and method (DF = 1, critical value for significance at 0.05 = 3.84)

Construct	χ^2	p-value	Significant	Odds Ratio	Effect Size
Powerful	4.58	0.03	Yes	2.48	0.17
Refined	4.13	0.04	Yes	2.15	0.16

The chi-square statistic provides evidence to accept the alternative hypothesis. The observed frequencies of 'behavioural' scenarios suggests that there is an association between evaluation settings and the frequency of 'behavioural' scenarios recalled by assessors, although a moderate/weak effect size was found.

As the frequencies for comparison based criteria also showed a similar relationship between the SQ evaluation settings, a chi-square test of association was carried out investigating the frequencies of comparison based decision-making criteria and evaluation settings. The hypothesis for interpreting the chi-square result are:

- *Null Hypothesis (H_o) – There is no association between the usage of comparison based decision-making criteria and the evaluation method.*
- *Alternate Hypothesis (H_a) – There is an association between the usage of comparison based decision-making criteria and the evaluation method.*

Table 7.8 presents the results of a chi-square test carried out to understand if comparison based decision-making criteria had an association between evaluation settings.

Table 7.8: Chi-square (χ^2) values for examining comparison frequencies and method (DF = 1, critical value for significance at 0.05 = 3.84)

Construct	χ^2	p-value	Significant	Odds Ratio	Effect Size
Powerful	3.49	0.06	No	0.46	0.20
Refined	4.98	0.02	Yes	0.49	0.25

The chi-square statistics reveal that the null hypothesis should remain when interpreting the frequency of comparison based decision-making criteria for powerful questions between evaluation settings. However, when considering the refined measure, a significant chi-square value was found which suggests that the alternate hypothesis should be adopted. The results suggest that there is an association between assessor's usage of comparisons and the evaluation method when evaluating the refinement of a vehicle.

7.4. Discussion

This study aimed to identify the information assessors use when they evaluate vehicle SQ in a structured evaluation and in a market research survey. Through the use of a novel approach which used a Verbal Protocol method this study identified four classes of decision-making criteria which were used by assessors. Assessors were found to evaluate vehicle SQ using information related to i) the attribute, ii) behavioural scenarios, iii) expectations and iv) comparison based criteria. The criteria are summarised in Table 7.9 will be used in subsequent studies in this thesis.

Table 7.9: Summary of the decision-making criteria used by assessors

Decision-Making Criteria	Definitions
Behaviour	Action, usage or self-reported behaviour
Comparisons	Sounds experienced or similar sounds
Expectations	Assumptions of vehicle
Attribute	Descriptive of the stimulus

The results observed in this study are suggested to differ from existing language based research as this study required assessors to think-out aloud and evaluate the sounds rather than to describe the sounds experienced (Altinsoy et al., 2012) which mainly consisted of descriptive results.

7.4.1. Frequencies of decision-making Criteria

A market research evaluation used a greater frequency of 'behavioural' scenarios in contrast to a listening room for both powerful and refined question sets. These differences were statistically significant and were suggested to have a moderate effect on the sample. Odds Ratios were calculated and suggest that assessors taking part in a market research survey are more than twice as a likely to use 'behavioural' scenarios than in an structured evaluation set in a listening room. The 'behavioural' scenarios verbalised by assessors included personal accounts of interacting with vehicles and performed driving manoeuvres. For instance, assessors in the market research survey used driving scenarios such as approaching a set of traffic lights or even thinking about setting off on their journey.

In contrast, assessors in a structured evaluation relied upon the previously experienced stimulus in the evaluation (e.g., Comparisons) to help evaluate the questions presented. As expected, assessors evaluated the sound stimulus which was presented to them and evaluated the vehicle sound according to semantics which were presented in the evaluation and with some assessors relying on personally derived semantics of their own.

An interesting observation included individuals in a listening room evaluation to base their judgements on previous experienced trials in the same evaluation. An excerpt which supports these initial findings can be read from Chattophahyay and Alba's (1988) study. They suggest decision makers can use a previous judgement of an object, rather than form new judgements of product stimuli, which was also observed in this study. This phenomena is known as the 'order effect' where Pielemeier et al. (2001) report how assessors could base judgements and evaluations on the first stimulus presented. Due to the comparative nature of assessors judgements in a listening room, this study provides support for existing research that paired comparisons may be better suited for non-experts taking part in structured evaluations (Blommer, 1997).

Assessors in both market research settings and listening rooms may use additional information to help with evaluations, e.g., Expectations. Expectations coded in this study were defined as the assumptions which assessors perceived about the vehicle sound presented (structured evaluation) or perceptions of their own vehicle (market research survey) and were not directly presented in the evaluations (Chapter 3).

Interestingly, assessors in the structured evaluation setting made fewer references to the WOT stimulus when evaluating refined based questions. This suggests using WOT sounds may not be reflective for that particular question in the structured evaluation and may not provide engineers in NPD with the criteria assessors consider during post-market stages. However, this requires further research and may involve the use of additional structured evaluation environments such as Vehicle Simulators, which will be investigated in Chapter 8.

Although ‘behavioural’ scenarios in market research were identified to be statistically significant. The ‘behavioural’ scenarios used by assessors within the market research survey also differed in content. This difference in behavioural content could influence the way in which the evaluation process takes place and ultimately the response produced (Sudman et al., 1996; Tourangeau et al., 2000). As behavioural frequencies for both powerful and refined measures were found to be significantly associated to a setting, behavioural influences in SQ are recommended to be further researched. It is not yet considered by existing SQ methodologies to ensure that the ‘behavioural’ scenarios used by assessors should be set or defined in structured evaluations (Schulte-Fortkamp, 2006; Genuit, 2011), this therefore provides an opportunity to generate valuable knowledge.

Duration between Presentation and Evaluations in Surveys

One explanation which may cause individuals to use different criteria in structured evaluations compared to market research, could be caused by the durations between stimulus presentation and evaluation. Assessors made their evaluations almost immediately after the sound stimulus was presented in the listening room whereas assessors in the market research setting would have experienced their vehicles much earlier and would have had the opportunity to recall criteria to make their decision. This could influence the use of different memory stores, where the different mechanisms could provide different types of decision-making criteria used for evaluations. Ganzach and Mazursky (1995) noted that a delay in judgements could influence consumer judgement to be positively biased. Whereas if information was vivid in memory, judgements were more negatively biased.

Although actual responses in this particular study are not the focus of this research, they should be taken into consideration for future studies investigating the quantitative acoustic measures of SQ. In a later study, Mazursky (2000) found that a delay in product judgements could encourage the use of inferences and abstracts in evaluations, in contrast to a reliance of factual information should the evaluation be made immediately after presentation of the product. Further research investigating the influence of time between sound stimulus presentation and evaluation could be investigated with vehicles, which can be considered as rarer purchases in comparison to the low

value consumer products e.g., food products or stimuli from product packaging, which are often used in research to date (Ganzach and Mazursky, 1995; Mazursky, 2000).

Ownership and Experience

Although all of the assessors in this were vehicles owners, individuals taking part in the market research survey were found to use more behavioural criteria. This could be due to the target object (in this case vehicle SQ) being evaluated to be owned or not. The findings suggest that when evaluating a product attribute which is not owned by the assessor could encourage the use of expectations and comparisons when evaluating vehicle SQ. If the object under evaluation is owned, more 'behavioural' scenarios could be used. Interestingly assessors in the listening room did compare the sound presented to their owned vehicles. The literature suggests that the influence of product ownership could cause individuals to exhibit a preference for an item which is owned (Barone et al., 1997). Additional research is necessary to investigate the influence of vehicle ownership on product evaluations.

7.4.2. Theoretical and Practical Implications

The observations made in this experiment identified the criteria individuals use to evaluate vehicle SQ, which to date has not attracted the attention of researchers, yet was still identified as a gap in knowledge to which finding a solution was considered important by automotive experts (Chapter 6). The observations from this study provides knowledge of how customers evaluate product attributes in structured evaluations and market research. To date, this understanding was not known from the academic literature as decision-making research has focussed on developing models for idealised decision-making and has rarely described processes which actually occur (Presser et al., 2004).

Using naturalistic decision-making tools (Verbal Protocols), this study has identified the influences on assessors when they evaluate vehicle SQ and has also demonstrated how structured evaluations and market research compare with each other, e.g., difference in 'behavioural' decision-making criteria. The observations can further add to the body of

knowledge in SQ evaluations which provide an insight towards how assessors evaluate sound in market research evaluations, when no sound stimulus is presented.

The practical implications from this study provides engineers with knowledge of the criteria customers consider when evaluating vehicle attributes in a post-market evaluation to be considered much earlier in the NPD process where understanding behaviour is important (Chicos, 1995; Graves, 2010) and was expressed to provide deeper insights towards customer data (Chapter 6). Although specific recommendations cannot be drawn until further verified, this study raises new issues when regarding the usage of listening rooms in order to predict customer evaluations, which were found to have a lack of behavioural definitions. Defining the 'behavioural' scenarios within the evaluations requires further research and will be re-evaluated in Chapter 9.

7.4.3. Repeatability and Validity

Thought Listing Protocols (TLP) further aided the validity of the identified themes (see Chapter 5 for rationale). The TLP allowed a triangulation method to capture decision-making criteria used by assessors to develop the framework to code transcripts (Appendix B). As this part of the study was carried out without the experimenter being present, this could maintain a degree of validity of responses and reduce the influence of the interviewer on assessor's responses through their tendencies to appear favourable in the study (Olson and Bilgen, 2011).

7.4.4. Limitations and Generalisations

Inherently the methods which are compared have differences in the way they are conducted, however this is a naturalistic study which aims to determine how these methods in their representative manner could influence decision-making for vehicle SQ evaluations. In order to maintain the representativeness of methods used by the automotive industry, additional data capturing methods and questionnaire instruments were not used. This ultimately resulted in strict usage of questionnaire space to use existing questions used in the automotive and market research industry.

Although the market research survey collected many responses for evaluations, the focus remained on SQ. Additional research to accommodate other vehicle attributes can be carried out using the same method before generalising the results of this study, although the methods used for assessing other vehicle attributes remain similar.

7.4.5. Next Steps

Chapter 4 identified that a listening room was not fully representative of how assessors may experience vehicle sound, which is important for an evaluation as assessors should be given the opportunity to experience sounds from a range of operating conditions and so that they can assign the necessarily level of importance to attributes in the full context. As a result, the WOT sounds presented to assessors may not represent the way assessors drive or consider in their SQ evaluations as was found when evaluating interior quietness in a listening room and may cause individuals to focus too much on the sound attribute. Additionally the lack of visual data from the listening room may also influence the evaluation process.

Therefore, a method which uses more representative sounds which are presented to assessors as well as associated visuals is important to further research. An interactive Noise, Vibration and Harshness (NVH) vehicle simulator is suggested to overcome this issue where the sounds presented to assessors corresponds to how assessors driving in a virtual environment (Jennings et al., 2005). Since driver behaviour was considered as a potential way to enlighten experts (Chapter 6) and as a behavioural difference was captured in this study, it is suggested to carry out a Verbal Protocol elicitation technique for interactive NVH vehicle simulators. It would be beneficial to determine if an interactive NVH vehicle simulator can also elicit ‘behavioural’ scenarios earlier in NPD.

Comparisons of SQ evaluations and vehicle simulators have been made by previous research (Jennings et al., 2010) however, no research to date has accommodated market research surveys into SQ evaluation comparisons. Adopting the same Verbal Protocol approach from this study could allow a comparison of methods used throughout automotive NPD and could help further

the knowledge of the criteria individuals use and whether or not ‘behavioural’ scenarios are considered during the evaluation of non-experts in simulators.

7.5. Summary

For the first time, a comparison between a market research survey and a listening room evaluation has provided a unique insight into the evaluative criteria used by assessors which to date which was missing from experts knowledge and the available literature. This study captured the decision-making criteria used by assessors in SQ customer research approaches. The decision-making criteria verbalised by assessors during structured evaluations and market research can be categorised into four occurring categories 1) behaviour, 2) attribute specific 3) comparisons or 4) expectations. This has helped answer Research Question (2) and Research Objective (2 A).

It was found that assessors in a market research setting had a greater reliance on ‘behavioural scenarios’ when evaluating the SQ of a vehicle, and was significantly associated with a market research setting. Whereas assessors in a listening test relied on comparisons to make their judgements, which was found for both powerful and refined questions and was the strongest for refined questions. Interestingly, assessors also used previous judgements from evaluations when evaluating refinement. This may seem apparent however, researchers and experts working in automotive NPD may not be aware of the comparisons which are made by assessors and how they contrast to market research evaluations.

To further investigate the role of ‘behavioural’ scenarios in structured evaluations and market research, a study which uses an interactive NVH vehicle simulator provides a suitable opportunity to further the current state of knowledge. The next study could help understand the influence of a behavioural input on assessor’s decision-making criteria and can also help achieve Research Objective (2 B).

Additional applied research opportunities were also identified within the psychological discipline and include, e.g., investigating the role of vehicle ownership on SQ judgements (Barone et al., 1997) and investigating the influence of a time-delay between stimulus presentation and evaluation (Mazursky, 2000) in SQ evaluations.

Chapter 8
A Study Using Verbal Protocols in an Interactive Vehicle Simulator

8. A Study Using Verbal Protocols in an Interactive Vehicle Simulator

8.1. Introduction

This chapter presents a study which examines the decision-making criteria assessors use to evaluate vehicle SQ in an interactive NVH vehicle simulator and to understand if the way assessors drive in the vehicle simulator has an influence on the frequency of 'behavioural' scenarios used as decision-making criteria.

8.1.1. Rationale

From the previous study it was learnt that assessors relied on a greater frequency of 'behavioural' scenarios in a market research survey in comparison to a listening room structured evaluation (OR = 2.5). However, neither the market research survey or the listening room evaluation included a behavioural component in the evaluation process. The literature review presented in Chapter 4 suggests that a listening room structured evaluation cannot provide assessors with the full context of driving a vehicle, however it remains an important method used by engineers to set and define vehicle attribute targets in NPD (Chapter 2). The lack of context could limit the generalisability of results from listening rooms to be used for understanding how sounds are perceived in a vehicle.

Previous research suggests that the perception of interior SQ is affected by the listener's behavioural response (Bisping, 1998). Examining the decision-making criteria used by assessors when evaluating SQ in an interactive NVH vehicle simulator could help understand the influences on assessor's decisions when driving a vehicle.

The results captured in this study will be compared to the market research assessors' decision-making criteria from Chapter 7. This could help determine if the decision-making criteria used in interactive vehicle simulators can assist engineers and designers to anticipate how vehicle owners in market research evaluate vehicle attributes.

A literature review of SQ methods (Chapter 4) identified that NVH vehicle simulators can be used in NPD to set engineering targets to help meet customer needs, by allowing potential customers to drive and experience vehicles in a virtual environment without the need to develop prototypes. NVH vehicle simulators have also been compared with other structured evaluations, e.g., on-road evaluations and listening room evaluations (Allman-Ward et al., 2004; Jennings et al., 2010). However, NVH vehicle simulators have yet to be compared with market research evaluations and it is currently not known how assessors evaluate SQ in these settings. Understanding these two settings could identify additional strengths and weaknesses when using NVH vehicle simulators in automotive NPD.

8.1.2. Study Aim

This study aimed to understand the decision-making criteria used by assessors when taking part in a structured evaluation based in an interactive NVH vehicle simulator that creates real-time sounds depending on how assessors drive. The knowledge created by this study can help answer Research Question (2) and achieve Research Objectives 2 A and 2 B set in this thesis. This study can further help determine if vehicle simulators can be used to anticipate how vehicle owners evaluate vehicle attributes in post-market settings. Finally, the study can also help to understand whether the behavioural input of assessors in an interactive vehicle simulator influences the type of decision-making criteria used to evaluate SQ.

8.2. Method

The study continued using a Verbal Protocol elicitation technique (Chapter 3) to capture the evaluation criteria used by assessors in vehicle SQ evaluations.

Assessors

Twenty assessors (16 male and 4 female) took part in this study. The average age of an assessor was 34 years old and licences were held for periods between 4 and 36 years. Once assessors were recruited they were randomly assigned to an experimental group. There were 10 assessors in each group. Group A's assessors had an average age of 32 years and Group B's assessors had an average age of 36 years.

Study Design

A between-groups design was implemented which included two independent groups (Group A and Group B). The study included a driving element in a vehicle simulator, which was followed by an evaluation of vehicle SQ using existing questions from the previous study (Appendix B). In order to determine if a behavioural input had an influence on decision-making criteria, individuals in Group A were informed of the purpose of the SQ evaluation and Group B were not informed of the SQ evaluation. Previous research indicates that assessors evaluating the 'powerfulness' of the vehicle carry out harsher accelerations similar to those in a WOT manoeuvre (Jennings et al., 2010). This would suggest individuals in Group A could drive differently to those in Group B. Driver behaviour can be evaluated through the vehicle simulator's behavioural input channels, e.g., throttle position and brake pedal pressure etc. Additionally, the metrics regarding vehicle performance such as the speeds reached and acceleration rates can be calculated from time/speed graphs.

Equipment and Materials

A fully interactive NVH vehicle simulator was used. The simulator was based on a Jaguar XJ as the donor vehicle which is pictured in Chapter 4 (Section 4.3.2). A pair of Stax SR-303 electrostatic open headphones were used to present auditory stimuli to assessors inside the vehicle simulator. The driving route was created using a DTS Road Creator software which generated 3-D visuals. The route consisted of a range of operating conditions including slow speed and national speed roads. An example of the scene from the route is photographed in Fig. 8.1:

Figure 8.1: Screenshot of graphics presented to assessors

Two 'bullet' video cameras were used to capture (i) the assessor's interaction with the steering wheel and (ii) the assessor. An example of images is shown in Appendix C.

The vehicle model programmed to provide the dynamics of the vehicle in the virtual environment was based on a luxury vehicle driver model. A touch-screen interface as shown in Chapter 4 (Section 4.3.2) was used to present information to assessors and to capture assessors SQ responses. A portable sound recorder was also used to capture assessor's verbalised decisions.

Procedure

Assessors in both Group A and B were instructed that they would need to verbalise their thoughts A) while they drove and then B) when the SQ evaluation had begun. Assessors in Group A were informed that the evaluation's purpose was to evaluate the vehicle SQ. Assessors were introduced to the simulator and were informed of the controls needed to operate the vehicle. Once assessors were comfortable, the driving component of the study began. The experimenter remained in the vehicle during the evaluation to provide assistance if needed. At the end of the route, assessors were requested to turn the vehicle off and to evaluate the vehicles SQ on the touch-screen interface using an existing template to evaluate SQ (Appendix B – SQ Template). Assessors were asked to verbalise any decisions and thoughts they experienced during the evaluations. At the end of the evaluation, assessor's demographic data was collected (Appendix B – Debrief Sheet).

8.3. Results

This section is divided into four stages. The first focuses on analysing the vehicle's performance through acceleration rates and the average speeds achieved to determine if assessors drove differently between groups. Stage 2 focuses on the qualitative data captured when the assessors evaluate the vehicle's SQ. Once the qualitative results were quantified in Stage 3, they provided an indication of the relationships between structured evaluations and market research and the decision-making criteria assessors used (Stage 4). The specific steps of the results process are summarised into the following four stages:

Stage 1 – Analysis of vehicle performance data

- Understand how individuals drove using the NVH vehicle simulator by analysing descriptive data and using inferential statistics.
- Influence on quantitative SQ results

Stage 2 – Qualitative Analysis

- Transcription of Verbal Protocols.
- Code transcripts with framework developed in Study 2.

Stage 3 – Quantitative Analysis

- Content Analysis – quantify decision-making.
- Cronbach's Alpha levels for powerful and refined measures.
- Chi-square tests – Compare observed frequencies to determine statistical significance between Group A and B.
- Effect Sizes

Stage 4 – Comparison with Market Research

- Compare powerful and refined measures with market research observations.

8.3.1. Stage 1 - Analysis of Vehicle Performance Data

Behavioural/Driver Analysis

To determine if the assessors driving behaviour, had an influence on the decision-making criteria in the SQ evaluation, it was necessary to assess the performance measures provided by the simulators software. The simulator software captured a range of measures highlighted in Table 8.1.

Table 8.1: Vehicle performance measures for each group of assessors in the interactive vehicle simulator

Measure	Group	N	Mean	SD	Minimum	Maximum
Time (s)	A	10	374.82	79.03	267.60	508.80
	B	10	498.55	113.13	371.04	723.72
Average Speed (km/h)	A	10	67.93	14.73	47.63	91.28
	B	10	53.64	13.20	33.52	75.00
Max km/h	A	10	121.80	16.65	94.80	152.86
	B	10	104.62	25.18	70.83	149.78
Max RPM	A	10	3737.50	227.08	3417.00	4075.00
	B	10	3533.90	342.27	2874.00	4033.00
Max Throttle Position	A	10	75.64	20.25	50.30	100.00
	B	10	63.14	17.65	39.20	100.00
Throttle Position	A	10	24.22	5.93	17.80	37.22
	B	10	20.07	4.45	16.68	31.70
Rate of acceleration	A	10	0.79	0.28	0.43	1.25
	B	10	0.48	0.15	0.31	0.81

Acceleration rates were also calculated to provide a realistic understanding of how strongly the assessors accelerated as observing the throttle positions did not take into account the time of the applied pressure on the throttle pedal.

Inferential Analysis of Driver Behaviour

A one-way Analysis of Variance (ANOVA) was carried out on the vehicle performance measures which revealed a number of significant differences between Groups A and B. A statistically significant difference between the two groups was found when analysing the time taken to complete the route, $F(1,18) = 7.89$, $p = 0.012$. Group A assessors drove at higher speeds in comparison to Group B. The average speed of driving was also compared and revealed a significant difference, $F(1,18) = 8.68$, $p = 0.009$. A comparison of acceleration rates

showed strong significant difference between Group A and Group B, $F(1,18) = 9.92$, $p = 0.007$. The results suggest Group A assessors drove much faster and differently when informed to evaluate the sound of the vehicle in comparison to Group B who were not informed of the evaluative purpose of the study.

Influence on quantitative SQ results

In order to understand if driving behaviour had any influence on the way individuals scored the SQ of the vehicle, further inferential statistics were carried out on 'powerful' and 'refined' measures. Table 8.2 presents the results of the initial descriptive analysis carried out on the SQ scores received for 'powerful' and 'refined' measures.

Table 8.2: Mean and SD for powerful and refined SQ responses in the vehicle simulator

Measure	Group	N	Mean	Std. Deviation
Powerful	1	10	5.60	2.366
	2	10	4.20	1.989
Refinement	1	10	5.00	1.886
	2	10	7.20	1.229

When comparing the qualitative scores for the vehicle sound no significant difference was identified for the powerful measure using a one-way ANOVA, $F(1,8) = 2.05$, $p = 0.169$. However when comparing refinement levels between Group A and B, a significant difference was found, $F(1,8) = 9.55$, $p = 0.006$. This suggests individuals can also evaluate a vehicle differently depending on driver behaviour.

8.3.2. Stage 2 – Qualitative Analysis

Having identified a clear difference in the way assessors drove in the vehicle simulator, Stage 2 of this research involved coding the verbalised decisions recorded during the SQ evaluation. The same framework was used from Study 2 to code the transcripts. Table 8.3 presents a summary of the decision-making criteria used by assessors when evaluating vehicle SQ in a vehicle simulator.

Table 8.3: Description of the themes and examples from the transcripts which are used by individuals to evaluate SQ in an interactive vehicle simulator

Theme	Description of theme	Transcript Extract
Expectations	In an interactive simulator test evaluation, additional information was not given to assessors and can be considered as prior held information. These criteria represented expectations which were elaborated by assessors such as considering the vehicle segment, e.g., sports/premium/luxury.	*"I know Jaguars are pretty powerful cars, and that was not the sound I would expect."*
		"Sounded like what I expect a car to sound like."
		"..for such a large car, which will also have a large engine…."
		"it's quite a luxury car, you would expect it to be refined."
		"The context of sitting inside a Jaguar."
Comparisons	While assessors were evaluated the sound of the vehicle in an interactive simulator setting, some of the responses comprised of comparison based criteria towards assessors own vehicles.	*"…the majority of cars I go in, they sound quite exciting…"*
		"I was comparing the sound the engine made against the sound that the engine of the car I currently drive makes."
		"It doesn't sound like my car."
		"I have driven different cars."
		"I haven't experienced many cars, I only driven one so slightly better than that."
Attribute (Sound)	Assessors in the simulator environment used semantics from the scales presented and focussed on the sounds presented. Assessors also commented on the realism of the sound.	*"It's not coarse, it sounded very smooth."*
		"It was quite quiet, quite smooth."
		"It was quite loud."
		"It sounded realistic."
		"I think it was more the refined side….just more of the engine sound."
Behaviour	These included scenarios and behavioural components when evaluating the sound presented.	*"I did not feel that much of a rapid acceleration."*
		"It was not intrusive at high speed."
		"When I pressed the accelerator."
		"Just progressing through the gears."
		"When I was doing 80 mph."
		"I was trying to accelerate really harshly."
		"When you're cruising you want it to quieten down."

8.3.3. Stage 3 – Quantitative Analysis

Stage 3 of the analysis involved quantifying the codes from transcripts. This was carried out using a Content Analysis approach which was outlined in Chapter 5.

Content Analysis

The decision-making codes were quantified and are presented in Table 8.3. Table 8.4 presents the frequencies of decision-making criteria captured from both Groups of participants using the vehicle simulator.

Table 8.4: Frequencies of decision-making criteria for Group's A and B in a vehicle simulator

Measure	Group	Behaviour	Comparisons	Sound	Expectations	Total
Powerful	A	16	10	27	15	68
	B	22	5	25	7	59
Refined	A	19	6	29	8	61
	B	15	11	28	7	62

Due to the different proportions of codes, an observation of the results is not sufficient to make a comparison. Therefore, it is important to use inferential statistics in order to make a comparison between the available methods. Although 'behavioural' decision-making scenarios are selected as the focus of this research, additional observations from Table 8.3 such as the role of 'Comparisons' will be carried out. A comparison of all decision-making criteria will be further examined in detail in Chapter 9.

The frequency of 'behavioural' scenarios were observed to be greater for Group B when evaluating 'powerfulness' questions however, when evaluating 'refined' questions Group A drivers were observed to use more 'behavioural' scenarios. It is also apparent from Table 8.4, that the decision-making criteria related to the sound attribute received the highest frequencies.

Interestingly, it seems that 'comparisons' made by assessors are greater depending on how the assessors drove, for example comparisons for 'powerfulness' were greater when Group A assessors who drove faster evaluated the vehicle SQ. In contrast, when 'refinement' was evaluated Group B who drove more conservatively, used greater comparisons.

Before any inferential statistics can be carried out, it is important to determine the internal reliability of the measures which will be assessed in the analysis by using Cronbach's Alpha.

Cronbach's Alpha Tests

In order to examine the internal reliability of the measures, Cronbach's Alpha scores were carried out on the numerical responses assessing 'powerfulness' and 'refinement' which are presented in Table 8.5.

Table 8.5: Internal reliability scores for powerful and refined measures in a NVH vehicle simulator

Setting	Measure	Question	Alpha
NVH vehicle simulator	Powerful	JDP Acceleration CQI Acceleration Powerful/Weak	0.59
	Refined	JDP Interior Quietness CQI Interior Quietness Refined/Coarse	0.81

A value of 0.6 is usually considered as an acceptable threshold to assess the internal reliability of a measure, values below 0.6 can be questionable. As the alpha value for the powerful measure was close to the acceptable threshold, consideration of this will be taken into account when interpreting the effect sizes and strength of chi-square association measure.

Chi-square tests of Association

To determine the statistical significance between the behavioural decision-making criteria Groups A and B use in the vehicle simulator, a chi-square test of association was carried out to understand if decision-making criteria were influenced by driving behaviour. The following hypotheses were formulated to interpret the results of the chi-square test.

- *Null Hypothesis (H_o) – There is no association between the usage of 'behavioural' scenarios as decision-making criteria and driving behaviour.*
- *Alternate Hypothesis (H_a) – There is an association between the usage of 'behavioural' scenarios as decision-making criteria and driving behaviour.*

The results of the test for association are presented in Table 8.6. Values for chi-square exceeding 3.84 (DF = 1) provide evidence to reject the null hypothesis and to accept the alternate hypothesis.

Table 8.6: Chi-square (χ^2) values for examining behavioural frequencies and driver behaviour (DF = 1, critical value for significance at 0.05 = 3.84)

Construct	χ^2	p-value	Significant	Effect Size
Powerful	2.82	0.09	No	0.14
Refined	0.56	0.45	No	0.06

No results were found to be statistically significant, which maintains the validity of null hypothesis. This means that there is no association between the frequencies of behavioural decision-making criteria and the manner in which individuals drive.

It was observed form Table 8.4 that comparison frequencies may also have an influence in decision-making influences between vehicle simulators and market research settings. Therefore, a chi-square test of association was used to determine the association between comparison based decision-making and Groups A and B. The following hypotheses were formulated to interpret the results of the chi-square test.

- *Null Hypothesis (H_o) – There is no association between the usage of comparison decision-making criteria and the evaluation method.*
- *Alternate Hypothesis (H_a) – There is an association between the usage of comparison decision-making criteria and the evaluation method.*

The results of the chi-square test for association are presented in Table 8.7. A value over of chi-square over 3.84 (DF = 1) provides the justification to reject the null hypothesis.

Table 8.7: Chi-square (χ^2) values for examining comparison frequencies and driver behaviour (DF = 1, critical value for significance at 0.05 = 3.84)

Construct	χ^2	p-value	Significant	Effect Size
Powerful	1.17	0.19	No	0.09
Refined	1.80	0.17	No	0.12

The chi-square value provides justification to maintain the null hypothesis when examining the comparison decision-making criteria between Groups A and B. This shows that comparison comments are also not dependent on the way individuals drive.

The results provide evidence that the behavioural frequencies between Group A and Group B can be combined to represent NVH simulators method when being compared with market research.

8.3.4. Stage 4 – Comparisons of Simulator settings with Market Research

This stage of the analysis focussed on a statistical comparison between frequencies of decision-making criteria observed in a market research evaluation (Chapter 7) and a simulator used in this study. Table 8.8 presents the frequencies of decision-making criteria for powerful and refined measures which will be used to compare the behavioural frequencies between structured evaluations and market research.

Table 8.8: Frequency of decision-making codes for market research (MR) and interactive simulators (SIM)

Measure	Setting	Behaviour	Comparisons	Sound Focus	Expectations	Total Codes
Powerful	MR	22	12	32	20	86
	SIM	38	15	52	22	127
Refined	MR	25	12	30	11	78
	SIM	34	17	57	15	123

As a behavioural disconnect was identified in Chapter 7, a chi-square test of association was carried out between behavioural decision-making criteria. Table 8.8 also indicates that there is a difference between the frequencies of decision-making criteria related to the attribute. Therefore, a chi-square test will be run on attribute-based criteria also to understand if this influence is significant. First, using a chi-square to examine the behavioural based decision-making criteria between structured evaluations and market research was carried out. The following hypotheses were formulated to interpret the results of the chi-square test.

- *Null Hypothesis (H_o) – There is no association between the usage of 'behavioural' scenarios decision-making criteria and evaluation method*
- *Alternate Hypothesis (H_a) – There is an association between the usage of 'behavioural' scenarios decision-making criteria and evaluation method*

Table 8.9 presents the chi-square result of association when comparing behavioural based decisions between a vehicle simulator structured evaluation and a market research survey. For the test to be considered statistically significant the chi-square value should exceed 3.84 (DF = 1).

Table 8.9: Chi-square (χ^2) values for examining behavioural frequencies and evaluation method (DF = 1, critical value for significance at 0.05 = 3.84)

Construct	χ^2	p-value	Significant	Odds Ratio	Effect Size
Powerful	0.47	0.48	No	0.70	0.04
Refined	0.44	0.50	No	1.56	0.04

Table 8.9 shows that the null hypothesis should be retained. This suggests that there is no association between frequencies of behaviour and evaluation setting between a vehicle simulator and a market research survey and that the 'behavioural' scenarios can equally occur in either setting.

Although the greater sample size for assessors in a NVH simulator was used, the attribute based decision-making criteria was observed in Table 8.8 to showed a possible difference between evaluations. A chi-square test of association was therefore used between Attribute based decision-making criteria and the methods. The following hypotheses were formulated to interpret the results of the chi-square test.

- *Null Hypothesis (H_o) – There is no association between the usage of Attribute criteria decision-making criteria and evaluation method*
- *Alternate Hypothesis (H_a) – There is an association between the usage of Attribute criteria decision-making criteria and evaluation method*

Table 8.10 presents the chi-square measure when comparing the frequency of 'attribute' criteria between a full vehicle simulator and a market research survey

Table 8.10: Chi-square (χ^2) values for examining attribute frequencies and evaluation method (DF = 1, critical value for significance at 0.05 = 3.84)

Construct	χ^2	p-value	Significant	Odds Ratio	Effect Size
Powerful	0.03	0.58	No	0.87	0.03
Refined	1.20	0.27	No	0.81	0.07

The chi-square test showed a non-significant result which suggests that the null hypothesis should be maintained when comparing 'attribute' criteria between the evaluations. This means the level of attribute comments had no association due to the methods.

8.4. Discussion

The aim of this study was to understand the decision-making criteria used by assessors in interactive NVH vehicle simulators when evaluating SQ. This study was conducted also to understand if introducing a behavioural input into the evaluation had any influence on decision-making criteria used by assessors. Understanding this could help determine if assessors taking part in an interactive vehicle simulator considered decision-making criteria similar to those in a market research survey. Distributions of decision-making criteria observed from listening rooms and market research will be discussed in Chapter 9. In order to answer the research questions and objectives of this study, it is first considered important to determine if a behavioural difference between Group A and B had occurred.

Driving Behaviour and Decision-Making Criteria

It was interesting to find a distinctive behavioural difference between the two conditions adopted in this study. Group A who were informed of the purpose of the study had higher acceleration rates and higher speeds in the simulated environment in comparison to Group B, who were not informed of the evaluation purpose of the study, drove less rapidly and had a significantly lower vehicle speed. This supports earlier suggestions made by Bisping (1998) where different behavioural inputs are suggested to influence the evaluation of SQ. More recently existing research identified assessors evaluating SQ drove differently when evaluating SQ measures such as ‘powerful’ and ‘refined’ (Giudice et al., 2008; Jennings et al., 2010).

In order to determine if this observation was due to the briefing or individual differences, the literature identified gender factors could possibly account for aggressive driving behaviour (Shinar and Compton, 2004). The authors found that male drivers accounted for more than 86% of the aggressive drivers in their study. As female assessors had limited participation in this study due to simulator sickness (Section 8.4.1), both groups in this study were male dominant and therefore gender effects could be ruled out. This provides a degree of support that assessors drove more aggressively to evaluate vehicle’s SQ through WOT based manoeuvres (Giudice et al., 2008; Jennings et al., 2010).

Decision-Making Criteria used in a Vehicle Simulator

Requesting assessors to verbalise their thoughts while driving acted as a warm up to allow assessors to be comfortable with verbalising their thoughts. When assessors finished the driving, assessors were invited to evaluate the vehicles SQ using the same interface which was developed for the listening room interface. The transcripts were coded using the same coding scheme which was established in Chapter 7 and again was initially drawn as a framework in Appendix B. The four themes of evaluation criteria identified in Chapter 7 were again identified in transcripts from the evaluations of individuals in an interactive vehicle simulator.

The key observations between evaluations included assessors to base 'expectation' decision-making criteria to be directed towards the Jaguar XJ vehicle, and the influence of brand is suggested to influence decision-making inferring that the vehicle is a large car and therefore would have a large engine, is one of the examples of 'expectation' decision-making criteria which was observed.

Interestingly, 'comparison' based evaluations were directed between the vehicle simulator and with vehicles assessors drove. The focus of the 'attribute criteria' were consistent with existing studies investigating SQ and individuals described the sounds using either the semantics presented in the scales or through their own vocabularies.

'Behavioural' decision-making however included a range of driving scenarios such as accelerating harshly, progressing through the gears and cruising. Although the 'behavioural' scenarios used by assessors will be compared in depth in Chapter 9, it is interesting to observe that the behaviour reported in the evaluations was emphasised to be carried out by the assessor, suggesting that assessors could confidently assimilate themselves in the vehicle. This could be important when investigating vehicle attributes which may require an ownership context as part of the simulator study.

Comparisons with Market Research

This thesis is focussed on understanding the disconnects between market research and structured evaluations. A chi-square test revealed no statistically significant results between the evaluation settings and the 'behavioural' scenarios used during the method, which suggests that assessors are likely to use similar 'behavioural' scenarios regardless of the methods. This is supported with OR value (0.7) for the powerful measure. The refined OR measure (1.5) however suggests individuals may be more likely to report the usage of 'behaviour' scenarios in a market research survey than in a vehicle simulator, however the effect size and degree of association from the chi-square suggest the observed influence is small. A further analysis of the content of 'behavioural' scenarios between market research settings will be carried out in Chapter 9 to help understand the extent of the observations in this study.

8.4.1. Limitations and Generalisability

The results in this research captured the decision-making criteria from a range of assessors, each with varied levels of experience of driving. However, due to the low attendance of female drivers in this study, a degree of caution must be taken when generalising the findings to the wider population, subject to further demographical comparisons.

Five female assessors withdrew from this study due to experiencing simulator sickness symptoms. This has resulted as a limitation of the study. A similar phenomenon was observed in Mourant and Thattacherry's (2000) study who investigated the role of gender in simulator sickness. It was found that female assessors experienced greater discomfort symptoms than males in vehicle simulators (Mourant and Thattacherry, 2000). Their paper suggests that vehicle velocity could contribute towards the phenomena but further research is still needed to understand why females experience greater levels of simulator sickness than males.

8.4.2. Contributions to Knowledge

Interactive NVH simulators are intrinsic evaluation method in SQ within NPD (Williams et al., 2005) and have been used to provide a representative way of driving and to allow designers experience the vehicle using a behavioural input in comparison to listening room evaluations.

The existing rationale for using NVH vehicle simulators has directed the attention of researchers to compare simulators with listening room evaluations and on-road evaluations which have shown to provide better reliability and reduce costs to build prototypes as a result of using vehicle simulators (Jennings et al., 2005; Beresford et al., 2006). However, existing research has neglected comparisons with how assessors evaluate sound in market research evaluations. This study therefore has identified an additional advantage for using simulators in NPD, which is to appreciate the influences facing individuals in a market research survey when vehicle owners evaluate vehicle features. This knowledge also validates the usage of simulators earlier in NPD. As a result of this study, engineers can use NVH vehicle simulators help anticipate how vehicle owners could evaluate a vehicle using market research.

8.5. Summary

This study has helped understand the decision-making criteria individuals use to evaluate SQ in a full vehicle simulator set in a structured evaluation setting. The rationale behind this study was to determine the influence a behavioural input has on assessors decision-making criteria.

Having observed a clear difference in the way assessors drove in the vehicle simulator, decision-making criteria between the two groups were compared. No significant associations were identified from the analysis which suggests frequencies of 'behavioural' decision-making criteria used by assessors is not influenced by different driving styles. However, a significant difference in the evaluation of the vehicles refinement was observed to be caused by driver behaviour, suggesting that the way assessors drive could impact evaluation scores.

This study found that a behavioural input in the structured evaluation resulted in greater 'behavioural' scenarios to be used by assessors. Frequencies of 'behavioural' criteria were found to have no association between market research evaluations and are suggested to elicit similar frequencies of 'behavioural' scenarios by assessors. Therefore, this study has identified an additional motivation to use simulators earlier in NPD, which to date had not been anticipated by the available literature. A further analysis of all three methods will take place in the General Discussion (Chapter 9).

Chapter 9
General Discussion

9. General Discussion

9.1. Introduction

This chapter will review the findings of this research and draw out the main contributions to knowledge and finally, the wider implications of the results will also be discussed.

9.2. Understanding the Decision-Making Criteria Used by Assessors to Evaluate Vehicle Sound

It was found that assessors evaluate vehicle SQ using four classes of decision-making criteria which were identified using a Verbal Protocol elicitation method. Table 9.1 presents the summary of the identified criteria used by vehicle owners during their evaluations of vehicle SQ either in a market research survey, a structured evaluation set in listening room or in a structured evaluation using an interactive vehicle simulator.

Table 9.1: Summary of decision-making criteria from Studies 2 and 3

Decision-Making Criteria	Definitions	Example
Behaviour	Action, usage or self-reported behaviour	"…Setting-off from Traffic Lights.."
Comparisons	Sounds experienced/comparisons drawn with	"...Previously owned car..."
Expectations	Assumptions of vehicle	"..Sports/Premium.."
Attribute	Descriptive of stimulus	"..Loud...","…Quiet…"

Validity of Qualitative Data

Chapter 5 (Research Methodology) outlined criteria (Taylor, 2001) which could be used as a framework to assess the validity of the qualitative data. One of the first measures to assess the validity of qualitative data is to compare the findings with the literature and if possible, similar studies. This is difficult for the current research as there are no available decision-making criteria studies to date which specifically examined the evaluative aspect of SQ and compared them to market research settings. Therefore, a broader search was considered to bring the results of this research into context of the available literature.

As the ‘attribute’ based-criteria in this thesis shares elements with language and semantic studies, a comparison with previous descriptive studies reviewed in Chapter 4, was made. Table 9.2 reminds the reader of the main language categories used by assessors in a listening test (Altinsoy et al., 2012).

Table 9.2: The language used by assessors in a listening room environment (Altinsoy et al., 2012)

Study	Description of Study	Categorised Language	Description
Altinsoy et al. (2012)	The study examined the language or semantic space used by customers when evaluating vehicle sounds.	Signal	Terms related to the sound signal
		Physical Properties of Product	Comments related to the vehicle, e.g., luxurious, small or light
		Emotional terms	Language such as threatening or aggressive
		Association with Product	Sporty or luxurious

It is evident that the ‘Signal’ comment identified by Altinsoy et al. (2012) shares similarities of criteria received in this research categorised under ‘Attributes’. Similarly, ‘associations with the product’ from their study share similarities with criteria categorised as ‘Expectations’ in this thesis. However, ‘physical properties of the vehicle’ and ‘associations with the product’ which are presented in Table 9.2 appear to address the same finding. The categorisation by Altinsoy et al. (2012) may not be clearly distinguished. As their study is focussed on the descriptive element of SQ, there are aspects which are not identified in empirical research to date, e.g., the role of ‘behavioural’ scenarios. The findings in Table 9.2 show a limited overlap with the observations from Chapters 7 and 8 of this thesis, and additional literature should be examined which aims to understand the relationships between evaluations earlier in NPD and those after NPD.

One example which shares common ground with pre-and post-market evaluations is a study by Gardial et al. (1994) who captured the evaluative criteria used by individuals during an interview setting, and asked them to comment on both pre-purchase and post-purchase related questions regarding their vehicles. Their categorised experiences from participants are presented in Table 9.3.

Table 9.3: Experiences used by participants in pre and post-purchase evaluations from Gardial et al. (1994)

Study	Description of Study	Categorised Experiences	Description of Category
Gardial et al. (1994)	The aim of the study was to identify differences between post-purchase product evaluation experiences with pre-purchase product evaluations. Evaluations were based on vehicles and not on a specific feature.	Attribute	Thoughts regarding the feature performance
		Consequences	Thoughts referring to the ownership/ Benefit/sacrifice
		Overall Product	Thoughts relating to the overall product
		Situation	Thoughts considering product usage/behaviour

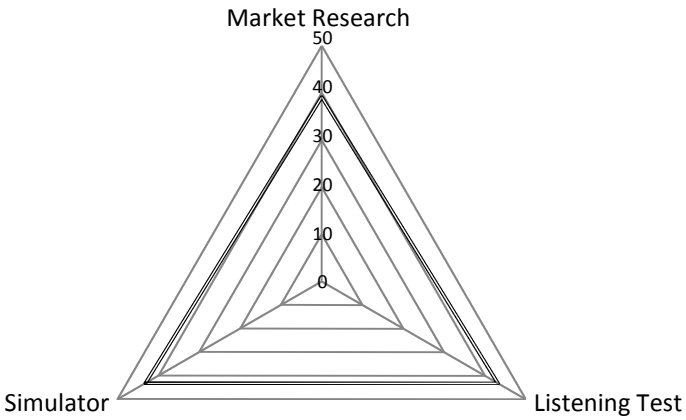
The results in Table 9.3 could provide a more representative comparison of criteria from Chapters 7 and 8 of the current thesis, rather than language based studies. Interestingly, 'situational experiences' were found amongst evaluative criteria from vehicle owners when reporting their experiences of purchasing a vehicle (Gardial, 1994) which provides support for identifying 'behavioural' decision-making criteria in the current study. Bodden (1997) further supports the role of behaviour as part of the cognitive influences on assessors during SQ evaluations, which can include an interaction or behavioural component with the sound source. The available literature has suggested that 'behavioural' influences can contribute towards the evaluation process, but very few studies to date have empirically shown this.

Although the categorised evaluative experiences of vehicle owners identified by Gardial et al. (1994) are evaluative based and also identified behaviour as an evaluative component, there are inherent differences between their study and the research in this thesis, such as the use of representative methods and independent samples. Gardial, et al. (1994) opted for a repeated measures design set in an interview. Although, it provides a comparison and support of the usage of 'behavioural' scenarios as evaluative criteria, the results from their study may not be fully generalised to automotive SQ nor to the existing methods automotive OEMs use to collect customer research e.g., structured evaluations or market research. This is due to their research design which relied on a single sample to capture both pre-purchase and post-purchase responses. The impact of this will be critiqued when examining differences in frequencies of decision-making criteria in the next section.

9.2.1. Frequencies of Decision-Making Criteria

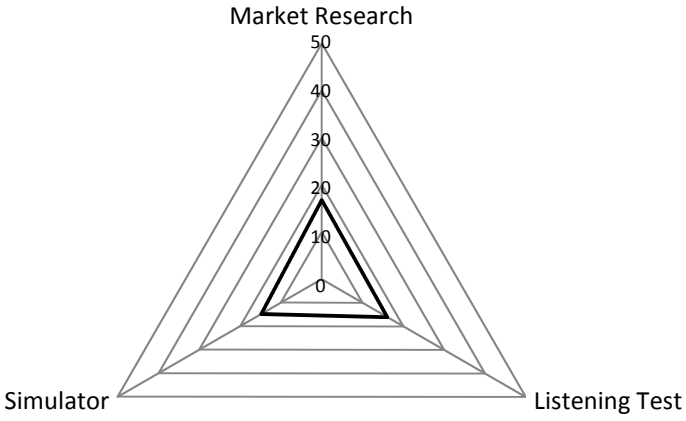
The prime aim of this research was to understand the influences on decision-making when assessors took part in structured evaluations and market research evaluations. This could help refine the investigated methods so that the sources of customer data identified in Chapter 6 may be better understood by automotive engineers. In order to understand any difference in decision-making criteria between methods, frequencies of the types of decision-making criteria used by assessors were identified using a Content Analysis approach (Hsieh and Shannon, 2005). The total classifications of criteria which were coded for each method are displayed in percentages in Fig. 9.1 (a-d), using radar graphs:

(a)



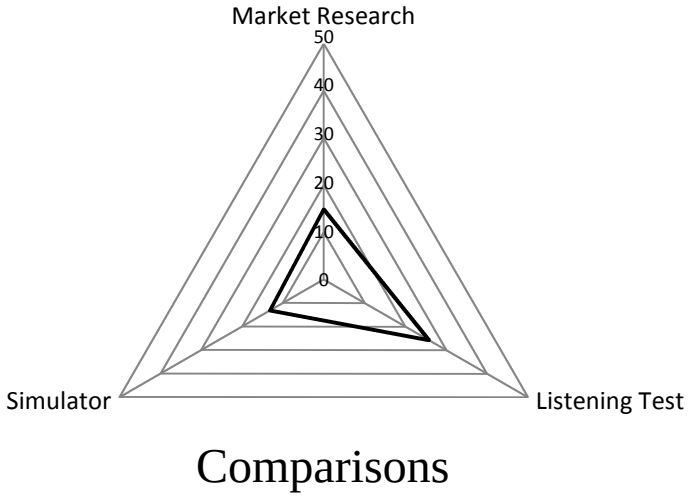
Attribute

(b)



Expectations

(c)



(d)

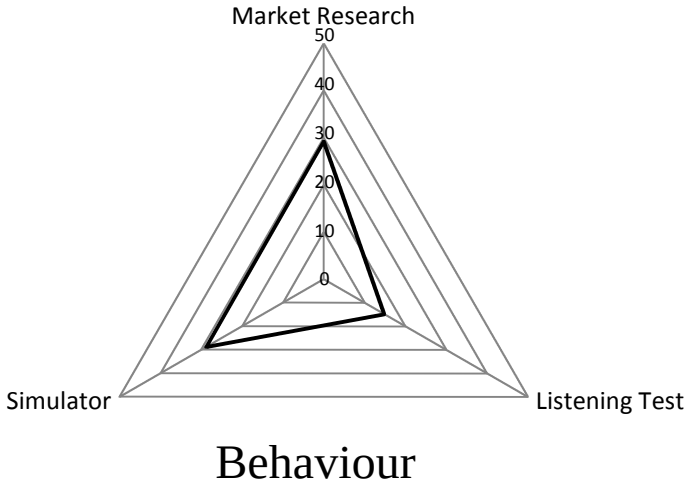


Figure 9.1: Frequencies of the decision-making criteria observed for a market research survey (MR) (n = 159), a listening room (LR) (n = 152) and in a simulator (SIM) (n = 250), where n refers to the total number of codes

Attribute Criteria

Figure 9.1 (a) presents the percentage frequencies of observed 'attribute' criteria. The frequencies of 'attribute' decision-making criteria were similar across evaluations (MR = 37%, LR = 42% and SIM = 43%). The 'attribute' decision-making criteria received the highest frequencies per method in comparison to other criterion, suggesting that respondents successfully responded to the focus of each sound question. Interestingly, the listening room and simulator achieved similar proportions of 'attribute' codes, which suggests assessors taking part in interactive simulators are also able to focus on the sound of the vehicle.

Expectation Criteria

Figure 9.1 (b) shows that assessors taking part in the market research setting expressed a greater tendency to use 'expectations' as decision-making criteria (MR = 18%, LR = 17% and SIM = 14%). Similar proportions of 'expectation' criteria were found for other methods. This could be explained as assessors taking part in a market research survey may have additional information about their vehicles which can be referred to in an evaluation. However, a previous understanding of evaluations would suggest a listening room should elicit the greater amount of 'expectations' due to the lack of contextual information provided about the vehicle in the evaluations in this research. With the lack of information, assessors may be more inclined to rely on 'expectations'. However, this was not found. The simulator setting and the listening room evaluation both achieved similar levels of 'expectations'.

Comparison Criteria

When observing 'comparisons' based evaluations from Fig 9.1 (c) it is apparent that individuals taking part in a listening room evaluation elicited this type of criteria the most often (MR = 14%, LR = 26% and SIM = 13%). Although 'comparisons' were also made in a market research setting the frequency was not as high. The lowest number of comparisons were found in the simulator study, yet were similar to the market research setting.

Behavioural Scenarios

A key difference between the methods relate to the frequency in which 'behavioural scenarios' were used by assessors. Figure 9.1 (d) shows that assessors in a market research and a simulator setting were found to have a greater reliance on 'behavioural' scenarios during their evaluations of sound (MR = 29%, LR = 14% and SIM = 28%) in contrast to the listening room setting which received the lowest proportion of 'behavioural' scenarios. However, assessors taking part in a simulator were observed to elicit similar proportions of 'behavioural' scenarios to those taking part in a market research survey.

9.2.2. Distribution of Criteria

In the case of more than one decision-making criterion being used by assessors, a further analysis was carried out to examine the overlap of criteria used by assessors. It was decided to produce a Venn diagram (Edwards, 2004) to further determine the overlaps of decision-making criteria for each of the settings researched in this thesis (Fig. 9.2). The possible overlaps of decision-making criteria were calculated using four sets in a Venn diagram (*Venn, cited in Edwards, 2004*).

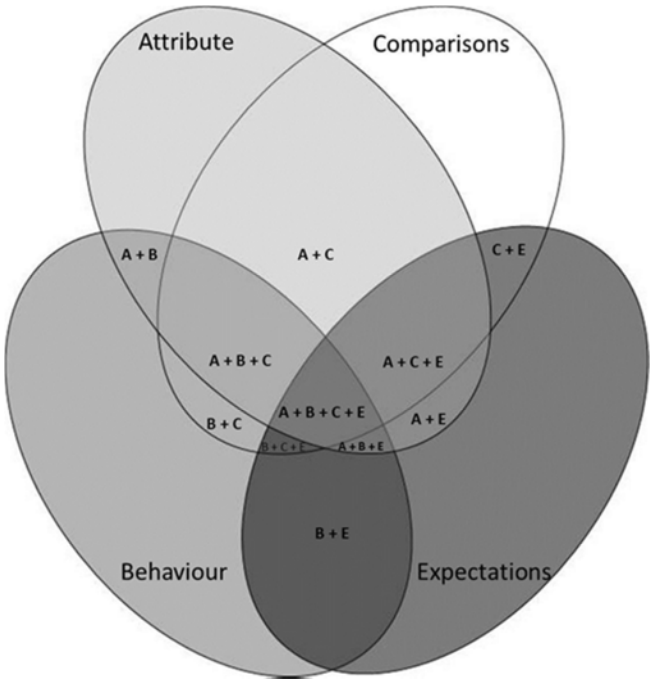


Figure 9.2: A Venn diagram highlighting the overlaps of decision criteria using 4 sets (Adapted from Venn 1880 cited in Edwards, 2004)

It should be noted that the areas of each section in Fig 9.2 are not representative of the frequency percentages. The distribution frequencies can be referred to in Table 9.4.

Table 9.4: Percentages of the distributions of decision-making criteria used in evaluations

	Distribution of Decision-making Criteria (%)		
Criteria	**Market Research**	**Listening Room**	**Interactive Simulator**
Attribute (A)	18.52	27.38	13.79
Comparison (C)	3.70	4.76	0.00
Behaviour (B)	7.41	2.38	5.17
Expectations (E)	4.94	1.19	0.00
A + B	20.99	4.76	35.34
A + C	7.41	20.24	11.21
A + E	3.70	8.33	9.48
B + C	2.47	3.57	0.86
B + E	1.23	4.76	1.72
C + E	1.23	2.38	1.72
A + B + C	8.64	4.76	3.45
A + C + E	2.47	7.14	3.45
B + C + E	8.64	0.00	0.86
A + B + E	6.17	3.57	9.48
A + B + C + E	2.47	4.76	3.45
Total	100	100	100

It is evident that decision-making criteria in a market research survey shares similarities with those taking part in a vehicle simulator. In contrast, a listening room evaluation did not elicit the same frequencies in similar areas in Fig. 9.2, as market research or simulator based evaluations. Although similarities in frequencies were found for market research and structured evaluations, the content of verbal protocols could differ, which is later identified as a potential area to further research in Chapter 10, as the information used by assessors could influence the evaluation score received for each question (Sudman et al., 1996; Tourangau et al., 2000).

Regarding the lack of 'behavioural' scenarios found in a listening room environment, this thesis suggests that assessors could have anticipated the 'behavioural' scenario from the sound stimulus presented. For example the few assessors who verbalised their 'behavioural' scenarios in a listening room evaluation, thought that the WOT sound presented was of a motorsport nature. This could provide individuals with a behavioural context, and therefore assessors may not place an emphasis on a 'behavioural' scenario.

The misinterpretation of behaviours in listening room evaluations was also found in a SQ study from 2009. The current findings coincide with Frère's et al. (2009) study which support the importance of defining behavioural contexts in a listening room. Their study aimed to identify which driving situations best suited a diesel engine. Assessors were given the option to select from an array of 'behavioural' scenarios. Ninety percent of their participants incorrectly matched the 'behavioural' scenarios with the sounds presented. For the presented acceleration sound, approximately 50% of the participants perceived the vehicle to be at a traffic light start, while the other 40% felt that the vehicle was at a constant speed. This supports the current findings from this research for the need to clearly define 'behavioural' scenarios used within SQ evaluations. However, this thesis suggests that this is not only this is not limited to listening tests and could also apply to vehicle simulators.

Gardial et al. (1994) examined the pre and post-purchase experiences of customers when evaluating their vehicles, which can draw similarities between market research and structured evaluations in a product development process. Situational/behavioural experiences were found

to be greater for post-purchase questions in comparison to pre-purchase questions which support the findings in this research. Although similar trends were found, as it was previously identified that the techniques used by Gardial et al. (1994) are not representative of the pre-purchase and post-market methods used in automotive NPD.

However, the available literature relating to the frequencies of criteria found in this research support the overall trend of the findings in this current research (Gardial et al., 1994) and rationalises the need to better define 'behavioural' scenarios in listening room evaluations (Frère et al., 2009), vehicle simulators, and market research.

9.2.3. Role of Behaviour

The findings from Chapters 7 and 8 show that structured evaluations such as interactive vehicle simulators can help anticipate how customers evaluate vehicles in market research. Although the frequencies of 'behavioural' scenarios are similar in interactive simulators and market research, the content of 'behavioural' scenarios can still differ. For example, when evaluating the sound of the vehicle from a stop, assessors would use situations where the vehicle was at a standstill, e.g., set of traffic lights or alternatively from roundabouts, some individuals even considered the start of their journeys.

However, when assessors were asked to evaluate the overall quietness of the vehicle, they would consider motorway driving. These 'behavioural' scenarios are currently not defined by existing evaluations and a difference in the content of 'behavioural' criteria could influence the subsequent evaluation response even though the same vehicle and attributes are being evaluated as was identified with 'refinement' scores in Chapter 8. This insight was not fully appreciated prior to this research, especially when comparing market research based methods to structured evaluation and is suggested for further research in Chapter 10.

Comparisons of Behavioural Criteria in Available Environments

Chapter 2 revealed the benefits for experts to fully understand customer data in NPD. As a result of this research, it was questioned whether structured evaluations which are carried out earlier in NPD can be used to anticipate results from a market research setting. This research

provides a comparison of the 'behavioural' scenarios used by customers in the available environments (structured evaluations and market research), which are shown in Table 9.5.

Table 9.5: A comparison of behaviour scenarios used in evaluation environments

Evaluation Environments			
Question	**Listening Room**	**Interactive Simulator**	**Market Research Survey**
Sound of Engine during Rapid Acceleration	Visualising a long road Accelerations	When the car reached 30-40 mph Accelerations	Setting-off from a roundabout Setting-off from traffic lights Overtaking on a country Lane
Overall Interior Quietness	Talking with someone in the car With music on Hearing the engine at idle	When the car was between 60-70 mph Travelling at high speeds 70-80 mph	Urban areas, rough road surfaces and potholes Motorway driving Holding a conversation at 60-70 mph
Powerfulness	Visualising the car on a road, or up-hill Visualising vehicle on road with other vehicles	Accelerations	Accelerations Setting off from Traffic Lights Country lane Right-lane Motorway driving
Refinement	Taking-off from standing Visualising a car on a racetrack	Progressing through the gears	City driving Countryside roads Motorway driving

Table 9.5 presents the potential behavioural influences with non-experts in customer research evaluations. The different scenarios provides additional support for experts to define 'behavioural' contexts when evaluating vehicle sound in each of the environments to prevent assessors from considering alternative 'behavioural' scenarios. The practical methods to achieve this will require further research which perhaps could be achieved with the use of multi-media and added contexts to existing measurement instruments.

9.3. Possible Explanations of Results

This discussion directs its attention to examine the possible causes for the findings interpreted from structured evaluations and market research by using broader theories provided by the psychological and SQ subject domains examined earlier in Chapters 3 and 4.

9.3.1. The Role of Memory on Decision-Making Criteria

It is suggested that the role of memory could determine how participants perceive products if the judgement is carried out immediately or after a delay (Ganzach and Mazursky, 1995; Mazursky, 2000). It is also suggested that reporting on ones behaviour as those found in market research evaluations can arise from autobiographical memory, which also forms part of long-term memory stores (Schwarz, 2007) and could provide an explanation for the results. Table 9.6 highlights some of the differences in the methodology of evaluations.

Table 9.6: Differences between market research and structured evaluations in terms of product perspective and memory stores involved

Approach	Sample Size	NPD Stage	Level of Control	Product Perspective	Memory Stores
Market research	Large	Post-Purchase	Low	Holistic	Long-Term
Structured evaluations	Small	Target-Setting	High	Attribute dependent	Short-Term

The way individuals make decisions in evaluations was outlined in Chapter 3. Individuals can retrieve information to assist them in their decision in an evaluation. Sudman et al. (1996) established a 4-Stage model (Chapter 3) of the survey response process which could be overlapped with Wickens et al. (2000) diagram which incorporates the role of memory stores in information processing. Within the same model, the decision-making criteria identified in this research can be mapped within the retrieval stages within evaluations, which is shown in Fig. 9.3.

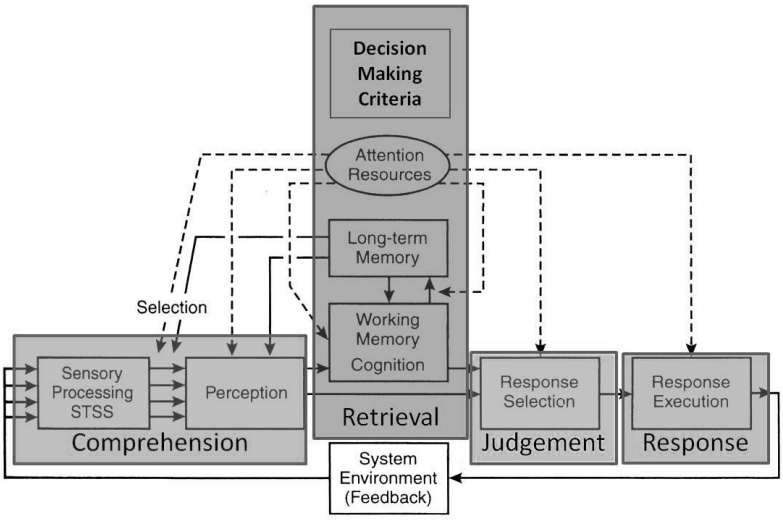


Figure 9.3: How the decision-making criteria could be mapped in the retrieval stages in information processing (Adapted from Wickens et al., (2000); Sudman et al., 1996)

The role of memory stores could influence the type of decision-making criteria used by assessors, depending on the method. For example, market research methods to date rely on assessors to make evaluations without any presented stimulus. This can encourage assessors to retrieve the 'behavioural' decision-making criteria from memory.

Structured evaluations in contrast present a stimulus to assessors to evaluate. As this stimulus is presented, it can be evaluated shortly after encouraging the working or short-term memory stores to play an active role. During the process, assessors can make a judgement and respond to the question. It is suggested that the SQ methods in this research utilise different memory stores and the difference in decision-making criteria identified could be partly explained by this divide (Ganzach and Mazursky, 1995; Mazursky, 2000).

More specifically to SQ evaluations, the role of memory can also influence the identification and cognitive appraisal stages in the sound perception process provided in Zeitler's et al. (2006) framework. The decision-making criteria identified in this thesis can also be categorised with the retrieval and memory stages which is shown in Fig. 9.4.

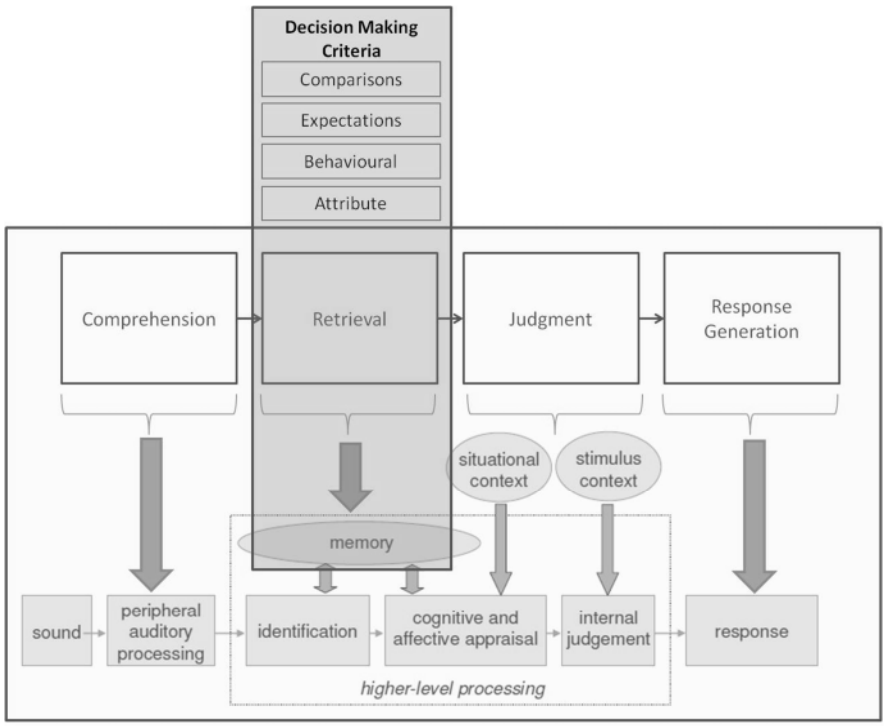


Figure 9.4: Mapping the evaluation process which occurs in sound evaluations combined with the decision-making criteria (adapted from Zeitler, 2006)

Figure 9.5 displays how the knowledge created as a result of this research can be placed amongst existing relevant literature, and specifically to the psychological processes in SQ evaluations. The resulting knowledge provided by this research could benefit SQ evaluations by being incorporated into the SQ methodology (Chapter 4) refined by Genuit (2011), and used specifically to provide insights in the qualitative analysis stage identified in the shaded area in Fig. 9.5:

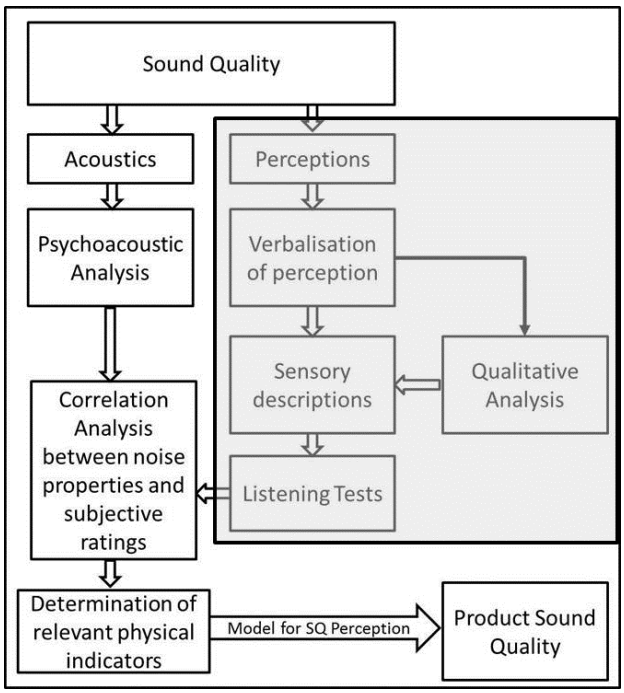


Figure 9.5: Shaded area identifying the areas where the findings of this research provide a novel contribution towards the information used by assessors in evaluations (adapted from Genuit, 2011)

9.4. Implications

This section will discuss the implications of the findings from this research.

9.4.1. Evaluation Methods

This research shows the need to adjust each of the methods investigated in this research to incorporate similar 'behavioural' scenarios. This thesis recommends the consistency of 'behavioural' scenarios should also be considered in evaluations. This can be achieved through questions which provide information of 'what' behaviour should be considered when evaluating the vehicle SQ, e.g., asking the assessor to consider a specific 'behavioural' scenario. However, the presentation and construction of such questions will need further research. Prior to this research, there was limited evidence which compared results from structured evaluations to market research.

Although this thesis potentially provides automotive OEM experts with enhanced knowledge of the influences on assessors, the findings could be adopted by those working in the market research industry. As OEMs could conduct evaluations internally, the impact for the findings to influence evaluation designs could be incorporated with minor delays. However, it may take

longer for independent market research agencies to adopt the findings in this thesis. Specific implications identified for methods are discussed next:

- **Market research –** The results of this research identify that market research emphasises more of the 'behavioural' aspect to be used by customers. Understanding this knowledge should help designers and engineers appreciate influences on assessors when evaluating structured evaluations and market research data. Furthermore, the observations in this thesis suggest that 'behavioural' scenarios need to be further defined in surveys.

- **Listening Rooms –** Although using WOT sounds are an established practice throughout the automotive industry, individuals still need to be provided with clear in-depth information about the vehicle under evaluation, as well as to define the behaviour which should be considered during the evaluation which can leave 'behavioural' scenarios to be misinterpreted from the sound stimulus. This suggests that the usage of WOT sounds also needs to be further researched as the sound stimulus is not always considered at the forefront of assessors decision-making, particularly when evaluating the overall quietness of the vehicle where comparisons could involve a greater role in assessor's evaluations.

- **Interactive Vehicle Simulators –** This setting provided fewer variations in 'behavioural' decision-making criteria that were verbalised by assessors. Although vehicle simulators were found to receive similar frequencies of 'behavioural' scenarios as those taking part in a market research survey the content of behaviours could differ. This research has provided an additional motivation for using simulators earlier in NPD, which is to understand how potential vehicle owners taking part in market research could evaluate the vehicle, before the vehicle is launched (Chapter 2).

9.4.2. Implications for New Product Development

This research could help to provide product designers and engineers working in NPD to consider the important influences in customers decision-making. By using scenarios important to customers earlier in NPD, could help OEMs to better achieve customer needs. The findings from this thesis could also be related back into the NPD in the 1st (Planning and Defining stages) and 4th (Product Validation) stages of NPD which were outlined by Sanongpong (2009) and presented in Chapter 2.

As 'behavioural' decision-making criteria were identified as a key influencing factor in assessors evaluations of a principal vehicle attribute, in order to further understand customer behaviour during vehicle NPD development could require a significant amount of resources. It is therefore suggested that these findings could be used to guide designers and engineers for complete-vehicle redesign levels in NPD (Weber, 2009). Developing new vehicle architectures and components could provide the opportunity to accommodate any engineering changes which can occur while carrying out evaluations which incorporate the 'behavioural' scenarios used by customers.

9.5. Reliability and Validity of Responses

This section elaborates on the validity and reliability guidelines which should be considered for evaluating qualitative data which were established earlier in the Research Methodology chapter.

9.5.1. Use of a Verbal Protocol Method

Chapter 5 established that the usage of a qualitative method can be verified by adopting recommendations provided by existing academic literature. The Verbal Protocol method adopted to observe the assessor's decision-making knowledge was carried out using recommendations by researchers who have also used Verbal Protocols for a range of applications such as survey methodologies (Sudman et al., 1996; Presser et al., 2004) and assessing the situational awareness of assessors in vehicles (Walker et al., 2008). The use of scripts and warm-up exercises for the Verbal Protocol elicitation technique were based on the recommendations found from the available literature (Chapter 3). To allow any additional

decision-making criteria to be captured, a triangulation method was also carried using TLPs (Cacioppo et al., 1997) which were collected for a listening room and a market research setting.

9.5.2. Repeatability

The methods used in this thesis were carried out under controlled environments and relied on the use of scripts to ensure that the research could be repeatable which can be found in Appendix B. The repeatability of this research can be assessed using internal reliability measures using a Cronbach's Alpha (Cronbach, 1990). Cortina (1993) provides guidelines for use using a Cronbach's Alpha and suggests alpha coefficient values greater than 0.70 are acceptable, which were all achieved for i) a market research survey ii) a listening room.

The internal reliability of the powerful measure in the simulator setting achieved an alpha value of 0.59. More recently, Götz et al. (2010) suggest a value of 0.6 is a common threshold of acceptability when interpreting Cronbach's alpha scores. The strength of chi-square associations between simulators and the market research survey was taken into consideration. The observed chi-square values were very low and allowed the correct hypothesis to be inferred.

9.6. Generalisations and Applicability

The findings of this research can be suggested to be generalised to the wider population of drivers and potential vehicle customers ranging from both the smaller/compact market to the premium vehicle segments. Although Study 3 had lower attendance from female assessors, generally those who took part in this research consisted of non-experts who had a broad range of driving experience (4-36 years), and were aged between 21-56.

Although the major impact of this research is for automotive engineers and market researchers concerned with vehicle SQ, the findings could contribute towards a better understanding of the underlying criteria customers use to evaluate a vehicle attribute. This can provide a platform for researching other areas in vehicle development or indeed non-automotive products where SQ plays an important role in the perception of products (Lyon, 2000) .The methodology provided

in this thesis could be generalised to examine a range of survey based tools and laboratory tests for assessing product attributes.

9.7. Contributions to Knowledge

This section presents the contributions of knowledge which have been generated as a result of this research:

Enhancing Automotive Experts perceptions of how vehicle owners evaluate Sound Quality

The study presented in Chapter 6 identified a series of insights that could allow engineers and managers working in an automotive OEM, to enhance their knowledge about customers which were currently missing from customer data. A particular insight was to understand the implicit influences on customers when they take part in evaluations. Insights towards customer behaviour and lifestyle were identified as potential ways to enhance the automotive experts' perceptions of how vehicle owners evaluated their cars. The findings from the studies presented in Chapters 7 and 8 provide the knowledge of the influences vehicle owners consider when evaluating a principal vehicle attribute – Vehicle SQ. This knowledge could be used to help address the needs identified by automotive experts in Chapter 6.

Using a Psychological Perspective in an Engineering Setting

Having applied a psychological approach to understand how assessors evaluated vehicle SQ in structured evaluations and market research surveys has provided new insights of the influences and potential cognitive mechanisms which are carried out in evaluations which can be used to supplement knowledge with the already existing engineering solutions to further design vehicle SQ. More importantly, the adopted approach has provided novel comparison of two distinct approaches of collecting customer research and has provided empirical evidence for the disconnects between structured evaluations and market research.

Evaluative Decision-Making Criteria used by Assessors in Vehicle Evaluations

Verbal Protocols carried out in structured evaluations and market research identified four types of decision-making criteria which were used by assessors (Section 9.2). These included 'behavioural', 'expectations', 'comparisons' and 'attribute' based criteria, which were later validated in an interactive NVH vehicle simulator setting. To provide a further understanding of the decision-making criteria, the occurrences of decision-making criteria between each evaluation were compared. Behavioural scenarios were found to be a key difference between listening room evaluations and market research surveys.

Validation of Vehicle Simulators

This thesis has provided empirical evidence that interactive vehicle simulations elicited a similar occurrence of 'behavioural' criteria as customer evaluations in market research conditions. This validates the usage of full vehicle simulators in NPD to help set SQ engineering and customer targets for the intended production vehicle. NVH vehicle simulators have been used as a SQ structured evaluation as they are considered more representative of driving than listening room evaluations, yet they can still maintain controlled experimental conditions which cannot be achieved for on-road studies. As a result of the knowledge generated by this research, it can now be suggested that the data obtained from vehicle simulators could help automotive experts to anticipate how future customers evaluate vehicle attributes in a market research evaluation. This can be considered as an additional motivation for using NVH vehicle simulators early in NPD.

Chapter 10
Conclusions

10. Conclusions

This research has identified the decision-making criteria used by assessors when evaluating a core vehicle attribute – vehicle sound. Although market research methods and structured evaluations can be used to incorporate customer responses into NPD for automotive SQ, no research was found which provides an in-depth understanding of the evaluative decision-making criteria used by assessors during vehicle attribute evaluations. Neither has existing research compared the decision-making criteria assessors used in each evaluation process. This gap in knowledge could prevent OEMs from fully interpreting customer data and also failing to consider the important influences or decision-making criteria customers use, once they have purchased their vehicle.

A preliminary study with an automotive OEM identified the specific sources of customer research data used within vehicle NPD, which ensured that this research used representative methods currently used by the automotive industry. The initial study also supported the approach adopted in this thesis, which was to focus on assessors' decision-making. Doing so could provide an insight of the criteria customers use in evaluations and 'how' vehicle attributes are evaluated which would otherwise be inaccessible to designers and engineers. Understanding the underlying criteria assessors use in evaluations can help improve an expert's knowledge of the customer's perceptions towards vehicle attributes and help them to focus on the important criteria customers consider in evaluations. The first study helped answer the first research question in this thesis, which reviewed the sources and use of customer data within automotive NPD.

By introducing a new perspective for understanding an engineering based problem, this research directs OEMs to focus on the important influences which new vehicle owners use in post-market evaluations, (e.g., market research surveys) and consider them earlier in NPD. Therefore, helping the OEM to extend its understanding of current customer needs and achieve further favourable market research based data for their vehicles.

Having adopted a psychological approach, a Verbal Protocol elicitation technique identified the decision-making criteria used by assessors in vehicle structured SQ evaluations and in a market research survey. The analysis of the Verbal Protocols from the second study revealed that assessors evaluated vehicle SQ using four distinct criteria, which were interpreted using a Thematic Analysis. Assessors in the second study focussed on A) the attribute, B) behavioural scenarios, C) expectations and D) comparisons of similar stimulus. Frequencies of the occurrences of their decision-making criteria were also analysed using a Content Analysis. For the first time, a comparison of the decision-making criteria used by assessors in a listening room and market research was carried out. It was found that assessors taking part in a market research survey used more 'behavioural' scenarios rather than to draw comparisons with other similar sounds, as was found in this case with a structured evaluation set in a listening room. Assessors taking part in a survey were twice as likely to use 'behavioural' scenarios in comparison to listening room evaluations. Behavioural differences between the approaches were found to be statistically significant.

When a difference in 'behavioural' scenarios was observed, it was considered important to use a structured evaluation which was not only more representative of driving a vehicle, but could also present vehicle sounds in real-time depending on the 'behavioural' input. Therefore, a third study focussed on the decision-making criteria assessors use in an interactive NVH vehicle simulator. The third study helped answer the second research question in this thesis, and provided additional knowledge of how a behavioural input in a NVH vehicle simulator influenced decision-making criteria.

The third study validated the coding of the second study and also identified the decision-making criteria assessors use during the evaluation. These findings were compared with the decision-making criteria from market research surveys which helped determine if assessors taking part in structured evaluations shared any similarities with the manner in which vehicle owners evaluate vehicle attributes, after they have purchased their vehicle. Assessors in the interactive NVH vehicle simulator were found to use similar frequencies of 'behavioural' scenarios to those used by individuals in a market research survey, which was illustrated by the overlaps outlined in

Chapter 9 and the chi-square statistics carried out in Chapter 8. As a result, this validated the usage of vehicle simulators to set customer targets earlier in NPD. This subsequently helped achieve Objectives 2 A and 2 B.

Although this thesis is focussed on SQ which provides rigour and depth to this investigation, there are inevitably some limitations. This research was not able to investigate other vehicle attributes, (e.g., vehicle dynamics, ride quality and comfort) which can also be assessed using structured evaluations and market research. Investigating additional vehicle attributes could increase the generalisability of the results by using the Verbal Protocol methods adopted in this thesis. As this research is set within an automotive context, where vehicles could be regarded as rare purchases, additional research for consumer products could be carried out, to further enhance the applicability of the results.

In conclusion, the vehicle evaluation methods studied in this thesis were found to influence the way assessors used criteria to make their decisions, e.g., 'behavioural' decision-making criteria. This research validated the use of NVH vehicle simulators in NPD, and identified an additional motivation for their usage as a method to examine the 'behavioural' scenarios customers consider in a market research survey.

The use of the novel approach adopted in this thesis has helped to generate an in-depth understanding of the decision-making criteria which customers use when they evaluate a principal product attribute during pre and post-market stages. Therefore, this thesis presents a comparison of two distinct approaches for collecting customer research by comparing their frequencies of decision-making criteria. As a result, for the first time, this thesis provides a practical demonstration of the disconnects present between structured evaluations and market research techniques.

10.1. Future Research

This section identifies potential areas for further investigation which could have the potential to generate further knowledge.

Efforts to define Behavioural Scenarios

In order to "improve" the methods to define behavioural context in vehicle evaluations and as the technological barriers to introduce multi-media are removed, respondents of surveys will begin to see many presentation methods in evaluations. Therefore, it will be useful for both market researchers and manufacturing industries to understand the influence of photographs, videos and audio stimuli on assessor's decision-making criteria. Further defining behavioural scenarios could also be achieved by asking more specific questions relating to the behavioural scenarios identified in this thesis for market research surveys and also to define specific scenarios for interactive vehicle simulators and listening room based evaluations.

Driver behaviour in Alternative Power-train vehicles

Alternative-powered vehicles are significantly different to internal combustion engine vehicles which could result in drivers to use the vehicle in a different way to ensure that the vehicle is used efficiently. This could result in different 'behavioural' scenarios to be considered when owners evaluate attributes of the vehicle. Adopting a similar methodology used in this thesis could be used to understand the important influences in decisions made by drivers when they evaluate alternative powered vehicles. This has the potential to provide a further understanding of customer needs and to identify the 'behavioural' scenarios for electric vehicles, which could also provide value for automotive OEMs.

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Appendix A – Study 1

Invitation letter to automotive OEM experts

Optimum Use of Customer Data/Opinions

Jaguar & Land Rover / Enprecis / WMG

International Digital Laboratory
University of Warwick
14th July

A brainstorming event to explore the collection and use of customer data

Agenda

9:30 Tea & Coffee

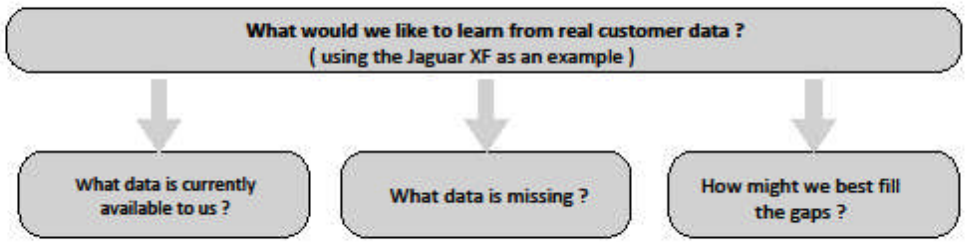
10:00 Introductions & Preliminary Exercise

10:30 Session 1

12:30 Lunch

1:30 Session 2

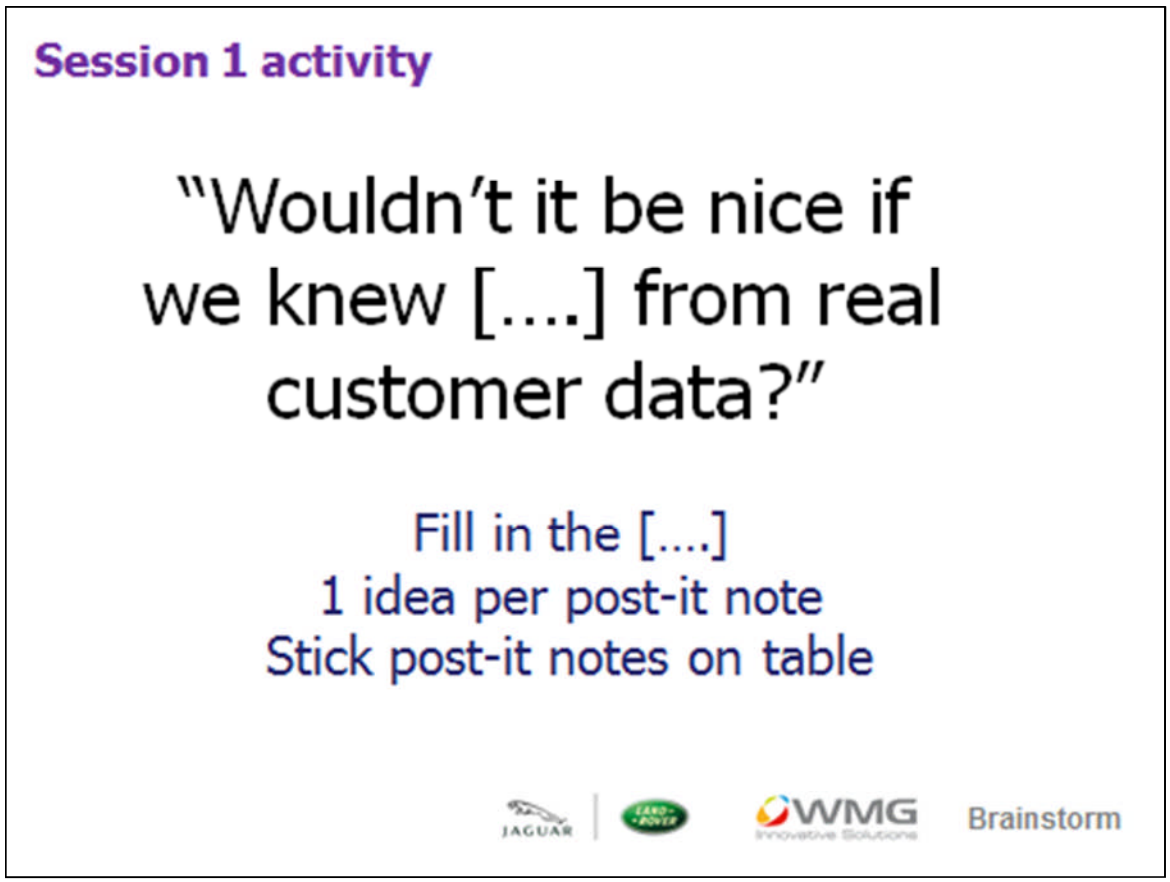
The sessions will be organised to help us critically review the currently available data, their strengths and limitations, and most importantly, to suggest how we might enhance current methodologies for using customer data within decision making.

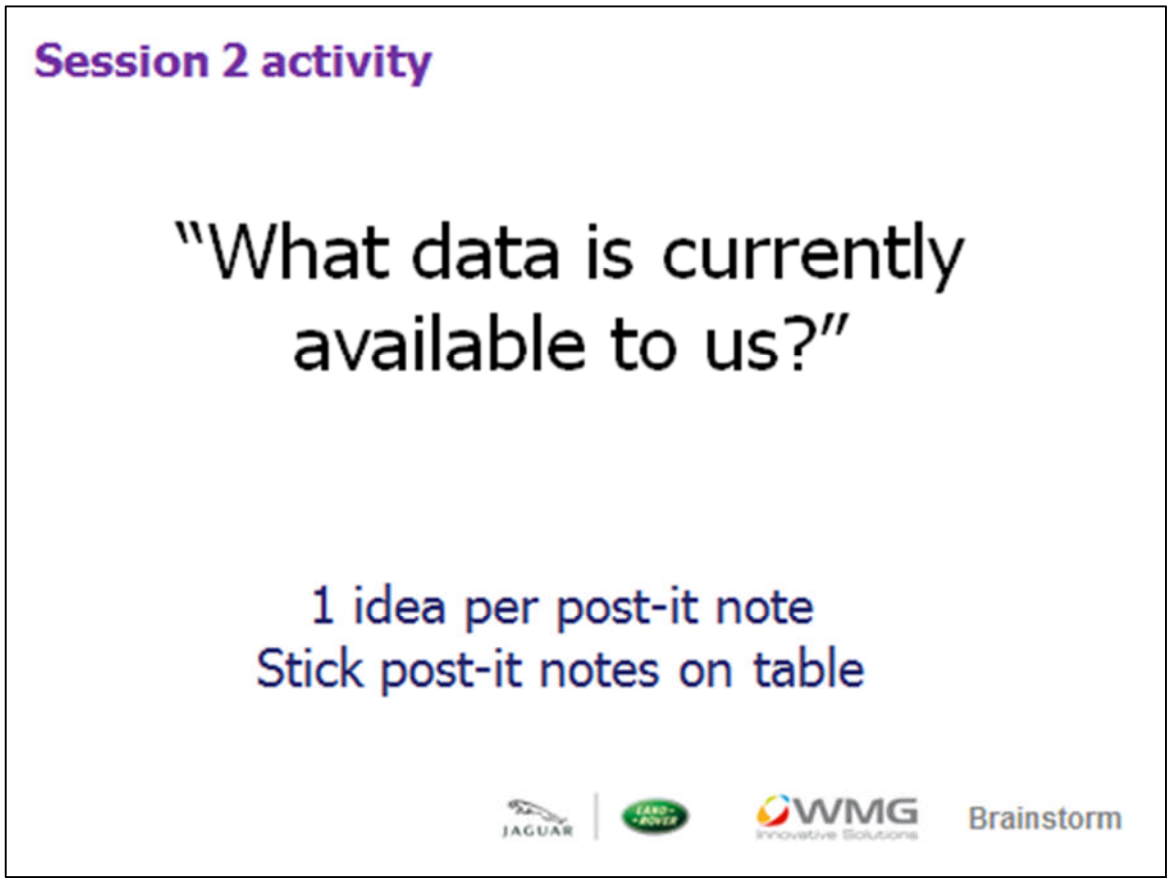


The Jaguar XF will be used as an example to allow focus for the discussions.

Outputs of the event will be collated by Mujthaba Ahtamad, a Psychology graduate, now carrying out PhD research on the "disconnect between customer data and structured engineering evaluations".

Materials


Session 1 activity
"Wouldn't it be nice if we knew [....] from real customer data?"
Fill in the [....]
1 idea per post-it note
Stick post-it notes on table
JAGUAR
WMG
Innovative Solutions
Brainstorm


Session 2 activity
"What data is currently available to us?"
1 idea per post-it note
Stick post-it notes on table
JAGUAR
WMG
Innovative Solutions
Brainstorm

Session 3 activity

"What themes are emerging?"

Cluster the post-it notes by theme

JAGUAR | LAND ROVER WMG Innovative Solutions Brainstorm

Session 4 activity

a) What new data needs collecting?
b) How do we make better use of existing data?

1 idea per piece of card (as many as you like)
Identify (a) or (b)

JAGUAR | LAND ROVER WMG Innovative Solutions Brainstorm

Data Capture – Label Making and Grouping Photographs

Label Making phase in Affinity Diagramming

Label Grouping phase in Affinity Diagramming

Debriefing and Feedback Form

Feedback Sheet

Thank you for attending and expressing your opinions at our brainstorming event.

Please can you take a moment or so to let us know what you enjoyed/liked about the event, what you think could be improved and finally, any additional comments .

Your comments are very important to us and will be completely anonymous. They will be used to help improve events we carry out in the future.

•What did you like about the event?

•What do you think could be improved?

•Additional Comments.

Appendix B - Study 2

Call for vehicle owners

THE UNIVERSITY OF WARWICK WMG Innovative Solutions

Call for participants,

I am currently looking for vehicle owners to take part in a series of experiments for my research.

The experiment itself is an evaluation exercise, where you will be asked to evaluate vehicle features and attributes. The experiment will last around 30 minutes.

The evaluation exercise is multi-disciplined which incorporates subject areas including **Engineering, Design, Marketing and Psychology.**

If you are interested in taking part, please contact me via e-mail to arrange a convenient time for you to participate.

Thanks

Mujthaba Ahtamad
m.ahtamad@warwick.ac.uk

Consent and Briefing Forms

THE UNIVERSITY OF WARWICK

WMG Innovative Solutions

Briefing Sheet for Survey

Thank you for your interest in my research which is looking into the judgement and decision making processes which are involved when individuals evaluate vehicle features.

You have volunteered to take part in a study which is known as a Cognitive Interview. Cognitive Interviewing is a technique where participants are asked to talk about their thoughts and decision making processes regarding specific events or exercises.

This particular study is adapting a form of Cognitive Interviewing known as Verbal Protocol Analysis. This technique asks individuals to say their thoughts aloud as they experience them when going through an exercise, in this case the exercise is a vehicle evaluation survey.

You will be asked to take part in a vehicle evaluation survey used by the marketing research industry. You will be asked to verbalise and speak the thoughts that come to your mind as you progress through the survey, as well the evaluation criteria you use to make your decisions.

I would like to emphasise that there are no right or wrong answers and the study is focusing on understanding how individuals evaluate their vehicles. So we do ask for you to be truthful and to act as you would normally, so that it is reflective of the real world. It is important that you verbalise your thoughts about HOW you made your judgement. Once you have completed the survey, I will ask you questions about the judgement making criteria which you may have used in market research survey.

The session will be recorded to help transcribe the interview afterwards to make sure it is reflective and valid.

If you have any questions please ask and make sure you have read and signed the consent form.

Mujthaba Ahtamad
2nd Year PhD Student.

Supervised by
Professor Jennings (WMG), Dr Cain (WMG) and Professor Lamberts (Dept of Psychology).

THE UNIVERSITY OF WARWICK

WMG
Innovative Solutions

Briefing Sheet for Structured Evaluations

Thank you for your interest in my research which looks into the judgement and decision making processes which are involved when individuals evaluate vehicle features.

You have volunteered to take part in a study which is known as a Cognitive Interview. Cognitive Interviewing is a technique where participants are asked to talk about their thoughts and decision making processes regarding specific events or exercises.

This particular study is adapting a form of Cognitive Interviewing known as Verbal Protocol Analysis. This technique asks individuals to say their thoughts aloud as they experience them when going through an exercise, in this case the exercise is a vehicle evaluation using a listening test.

You will be asked to take part in a vehicle listening test which is used by vehicle manufacturers and research institutes. You will be asked to verbalise and speak the thoughts that come to your mind as you progress through the listening test, as well as the evaluation criteria that you use to make your decisions.

I would like to emphasise that there are no right or wrong answers and the study is focusing on understanding how individuals evaluate vehicles features. So we do ask for you to be truthful and to act as you would normally, so that it is reflective of the real world. It is important that you verbalise your thoughts about HOW you made your judgement. Once you have completed the listening test, I will ask you questions about the judgement making criteria which you may have used in the listening test.

The session will be recorded to help transcribe the interview afterwards to make sure it is reflective and valid.

If you have any questions please let me know and make sure you have read and signed the consent form.

Mujthaba Ahtamad
2nd Year PhD Student.

Supervised by
Professor Jennings (WMG), Dr Cain (WMG) and Professor Lamberts (Dept of Psychology).

Participant No:

CONSENT FORM
Study 2: Understanding the Thought Processes Involved in Vehicle Evaluations.
Name of Researcher: Mujthaba Ahtamad

Please tick the boxes if you agree.

1. I agree to take part in the above study. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time. ☐

3. I understand that the interview will be recorded and will be used to transcribe the results for analysis. Mujthaba Ahtamad and his academic supervisors Professor Paul Jennings, Dr Rebecca Cain and Professor Koen Lamberts will have access to this. ☐

4. I confirm that I have read and understand the information sheet dated provided for the above study. I have had the opportunity to ask questions and have had these answered satisfactorily. ☐

Name of Participant: Date: Signature:

Instructions

Warm-Up Exercise

Practice speaking your thoughts with this warm-up exercise. Please complete the mathematical problems listed below. Emphasising on how you are answering the questions rather than the answer itself.

Bear in mind, that we would like you to say your thoughts out loud as you experience them.

Please talk through how you would answer these mathematical questions. We are not interested in correct answers but only the approach you use to answering the questions.

23	15	150	17	54	450
X 5	X 3	+273	X 8	X 4	+567
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

Prompt Script

Prompt 1 will be used if the assessor is expressing difficulty in understanding the questions in the survey or interpret the question in the wrong way. It can also be used if the participant is having trouble expressing their thoughts and verbalisations. Prompt 2 is used if there is a period of silence from assessors

Prompt 1 – Explain it using your own words this time.
Prompt 2 – Could you think out aloud

The next set of prompts can be used if the assessor is not expanding/elaborating on their decision making criteria.

Prompt 3– Can you further explain what you meant?
Prompt 4– What factors helped you make your decision?

The following prompts can be used to tell the assessor to proceed to the next question/section

Prompt 5 – Answer the question/s and proceed to the next question...
Prompt 6 – Proceed to section/question...

Instructions for Listening Test

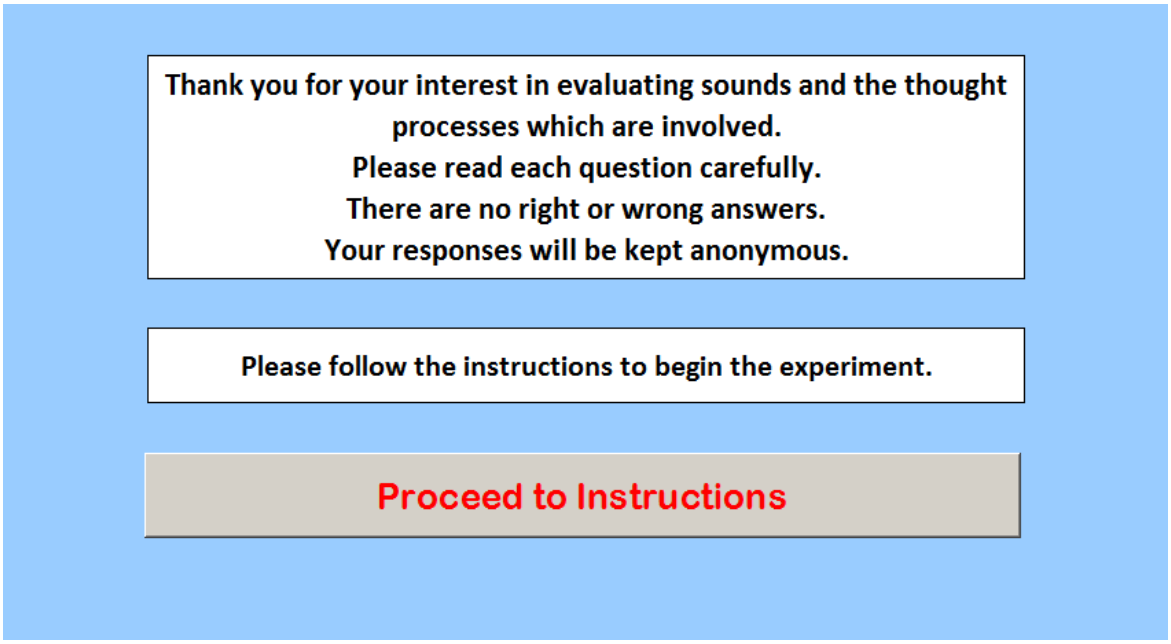
Instructions

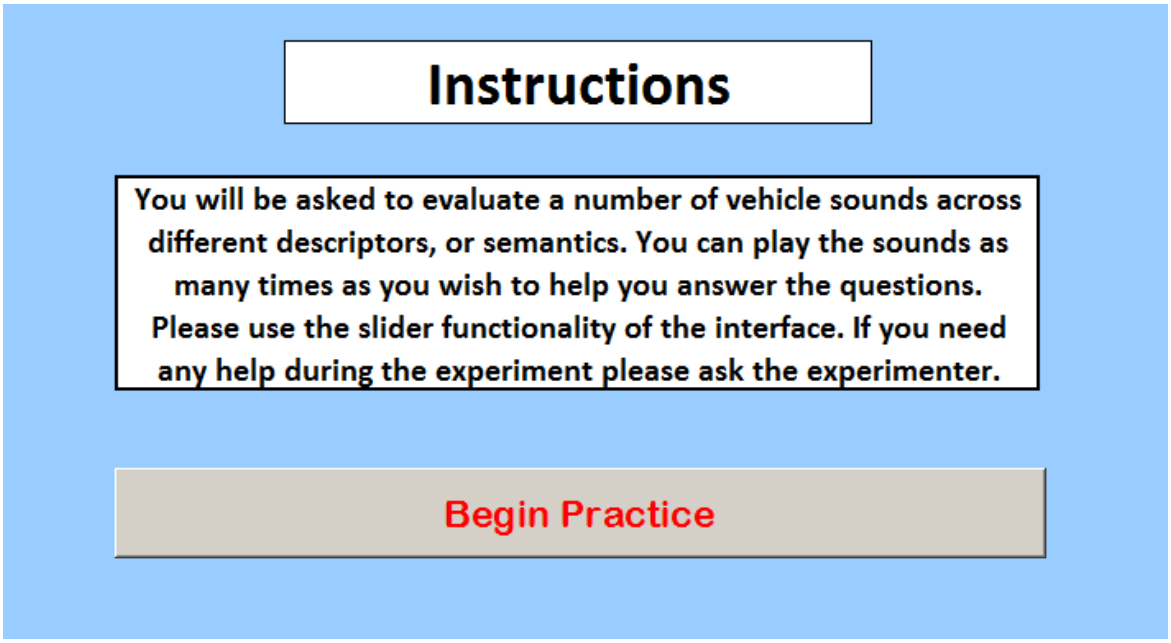
1) Complete the warm-up exercise
2) Please wear the headphones
3) Read each question out loud and describe what you experience/what goes through your mind before answering.

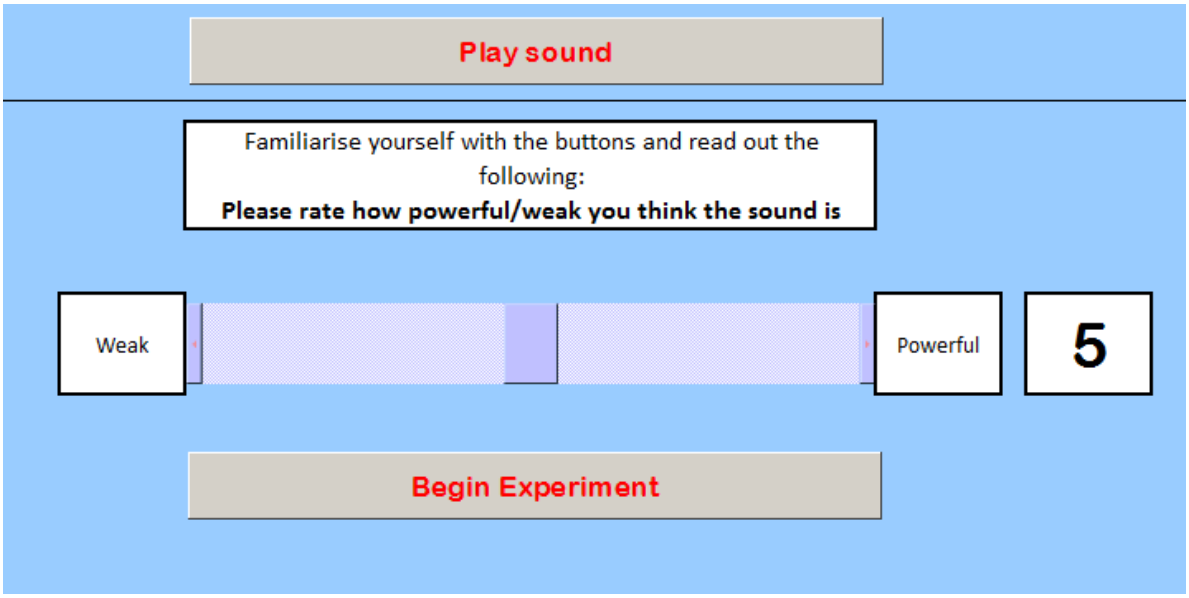
- Talk about the factors which will help you answer the question
- Answer using the slider scale/box
- Wait to be instructed to proceed to the next question
- The observer may ask you questions before you proceed

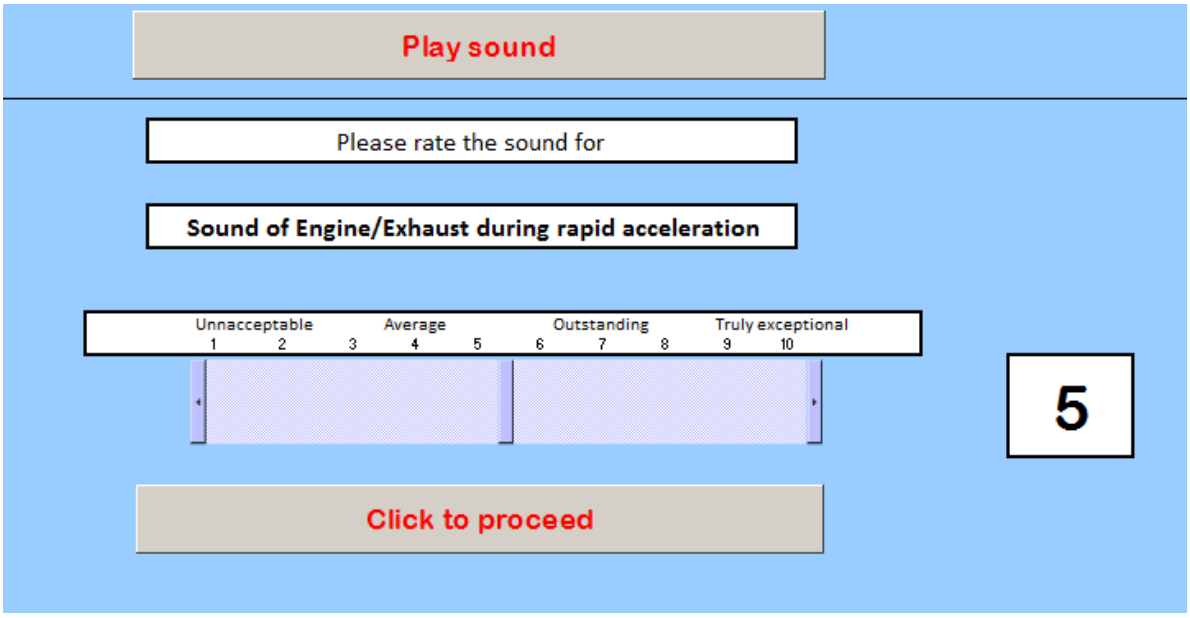
Listening Room arrangement

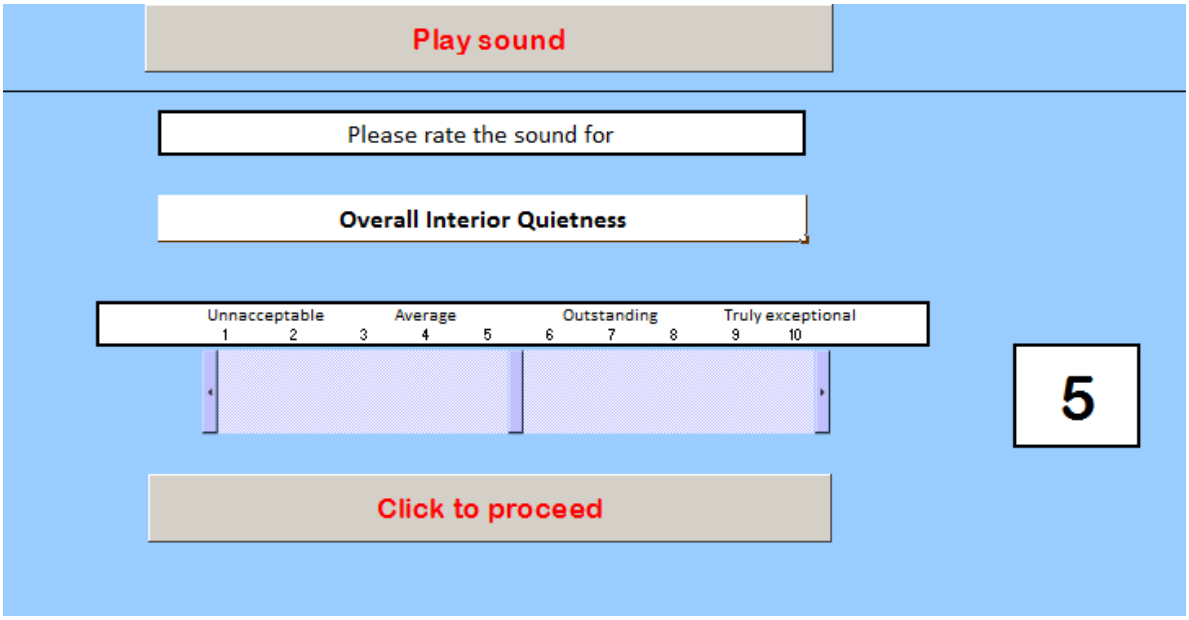
Experimental Materials – Sound Quality Template

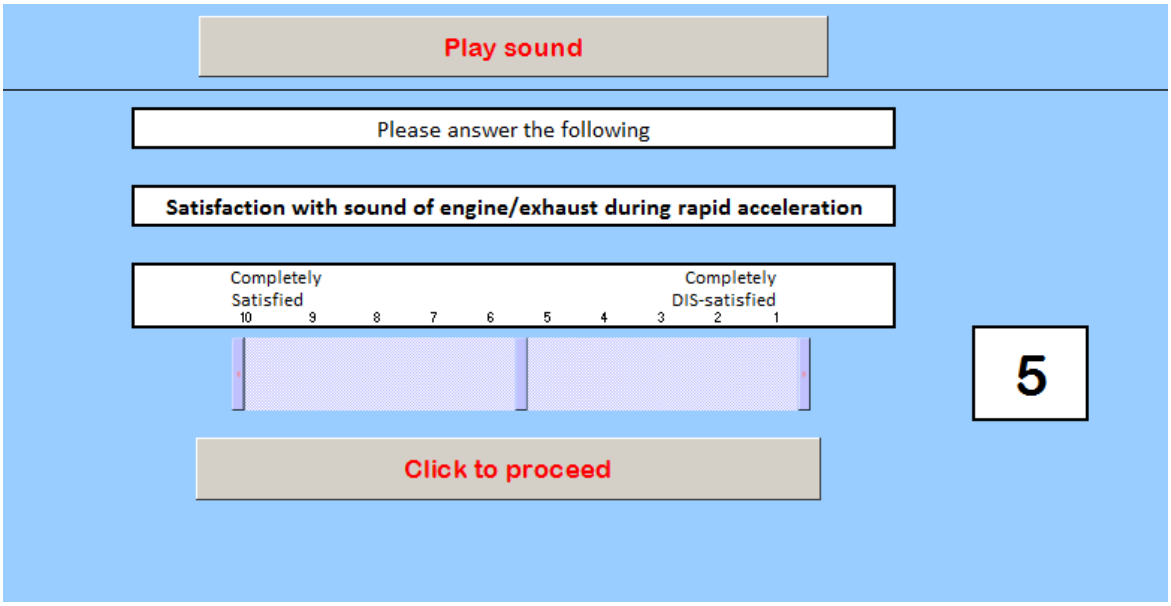


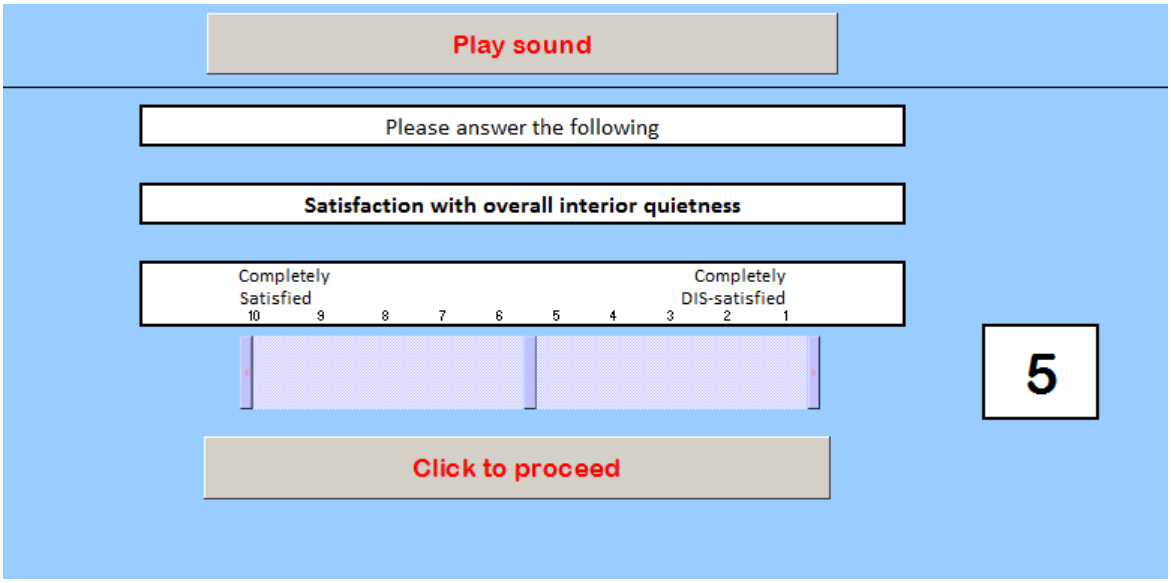



Play sound
Familiarise yourself with the buttons and read out the following:
Please rate how powerful/weak you think the sound is
Weak
Powerful
5
Begin Experiment


Play sound
Please rate the sound for
Sound of Engine/Exhaust during rapid acceleration
Unnacceptable
Average
Outstanding
Truly exceptional
1 2 3 4 5 6 7 8 9 10
5
Click to proceed


Play sound
Please rate the sound for
Overall Interior Quietness
Unnacceptable
Average
Outstanding
Truly exceptional
1 2 3 4 5 6 7 8 9 10
5
Click to proceed


Play sound
Please answer the following
Satisfaction with sound of engine/exhaust during rapid acceleration
Completely Satisfied
Completely DIS-satisfied
10 9 8 7 6 5 4 3 2 1
5
Click to proceed


Play sound
Please answer the following
Satisfaction with overall interior quietness
Completely Satisfied
Completely DIS-satisfied
10 9 8 7 6 5 4 3 2 1
5
Click to proceed


The evaluation is now complete.
Thank you for taking part.

Instructions for Market Research Survey

Instructions

1) Complete the warm up exercise
2) Complete Section 1 on the survey.
3) Read each question out loud from Section 2 and describe what you experience/what goes through your mind before answering.

- Talk about the factors which will help you answer the question
- Place your answer in the scale/text box
- Wait to be instructed to proceed to the next question
- The observer may ask you questions before you proceed

Market Research Survey

Vehicle Quality Survey

WMG Innovative Solutions

WMG official use:

WMG
International Digital Laboratory
Coventry
CV4 7AL

Instructions

Thank you for your interest in the WMG Vehicle Quality Survey. It is important that you take part, to give vehicle manufacturers important feedback towards producing a better vehicle and improving quality. You are reminded that your responses will be kept confidential. Please take your time in completing the survey.

1. About your vehicle

Make	Model	Current Mileage	Are you the primary user?
.....	.....	.....	.....
Auto/Manual	Date of purchase	Price	Year of Manufacture
.....	.....	.....	.....

Alternative vehicles you considered?

....

2. Your purchase decision

What were the important factors in your choice to buy the vehicle? (describe)

.....

.....

.....

What has delighted you about your vehicle? (describe)

.....

.....

.....

What has surprised you about your vehicle? (describe)

.....

.....

.....

3. What you like and don't like about your vehicle?

Please read each question carefully and give your responses using the 1 to 10 scale.

Engine &Transmission

	Unacceptable			Average			Outstanding			Truly Exceptional
	1	2	3	4	5	6	7	8	9	10
Performance during rapid acceleration from a stop	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Sound of engine/exhaust during rapid acceleration	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Smoothness of gearshift operation (Gear Changes)	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Rating of vehicle's fuel economy (Miles Per Gallon)	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Overall rating of vehicle's engine transmission	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩

Vehicle Exterior

	Unacceptable			Average			Outstanding			Truly Exceptional
	1	2	3	4	5	6	7	8	9	10
Front-end styling (headlights/grille area)	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Side-profile appearance and styling	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Rear-end styling (boot area)	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Sound of doors when closing	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Overall rating of attractiveness of the exterior	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩

Vehicle Interior

	Unacceptable			Average			Outstanding			Truly Exceptional
	1	2	3	4	5	6	7	8	9	10
Attractiveness of instrument panel and dashboard	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Look and feel of the steering wheel	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Overall interior quietness	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Pleasantness of audible signals (chimes, indicators)	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Overall rating of attractiveness of the interior	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩

4. Customer Satisfaction

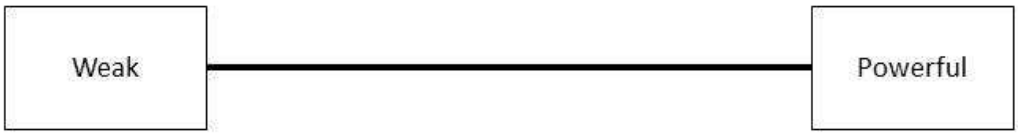
Please answer the following questions with regards to your satisfaction for the following features.

	Completely Satisfied									Completely DIS-satisfied
	10	9	8	7	6	5	4	3	2	1
How do you feel about the quality of your vehicle overall?	O	O	O	O	O	O	O	O	O	O
Satisfaction with Vehicle Exterior Design & Appearance	O	O	O	O	O	O	O	O	O	O
Satisfaction with Vehicle Interior Design & Appearance	O	O	O	O	O	O	O	O	O	O
Satisfaction with Overall Interior Quietness	O	O	O	O	O	O	O	O	O	O
Satisfaction with Sound of Engine/Exhaust During Rapid Acceleration	O	O	O	O	O	O	O	O	O	O
Satisfaction with Engine Performance	O	O	O	O	O	O	O	O	O	O
Satisfaction with How Solid and Well Built the Vehicle Feels	O	O	O	O	O	O	O	O	O	O

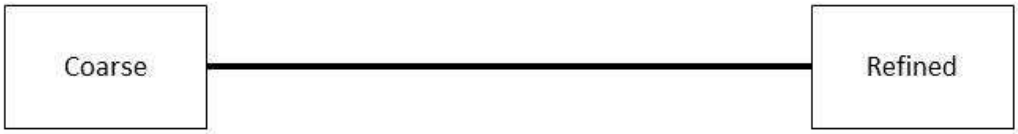
5. Vehicle Sound

Answer the question using the scale below, by marking your preference on the line.

Please rate how powerful/weak you think the vehicle sounds



Please rate how refined/coarse you think the vehicle sounds



6. Product development

Please use this space to tell us what you would like to see in future production vehicles.

7. About you and your personality

Gender: _____ Age: _____ Marital Status: _____

How many people under the age of 20 currently live with you: _____

Level of education you received: _____ How long have you held a driving license? _____

Where do you do most of your driving? (Please split them up into approximate percentages into the following)

Motorway ..... City Centre/Town..... Country roads.....

Please rate how characteristic the following statements are of you.

Example Scale 1- I don't feel that way at all. 2- I don't necessarily feel that way 3-I don't care one way or the other. 4- I feel kind of like that. 5- That's exactly how I feel.

I like driving on challenging roads.....	☐	I will tolerate some problems if I get the performance..	☐
Fuel economy is very important.....	☐	I would never buy a vehicle in the year it is released.....	☐
I want a vehicle that stands out from the crowd.....	☐	I tend to prefer vehicles that are larger.....	☐
I prefer an environmentally friendly vehicle.....	☐	To me, safety is more important than styling.....	☐
When I buy a vehicle I want the best in its class.....	☐	The brand name is very important.....	☐

Thank you

Thank you for completing the survey. Your responses are very important as they will assist vehicle manufacturers in improving vehicle quality.

✂

If you are interested in taking part in future studies or hearing more about the research please provide us with your contact details.

Thought Listing Protocol Materials

List the factors/thoughts you experience when you are asked about how ***Powerful*** a vehicle sound is

List the factors/thoughts you experience when you are asked about how ***Weak*** a vehicle sound is

Prompt Script

Prompt 1 will be used if the participant is expressing difficulty in understanding the questions in the survey or interpret the question in the wrong way. It can also be used if the participant is having trouble expressing their thoughts and verbalisations.

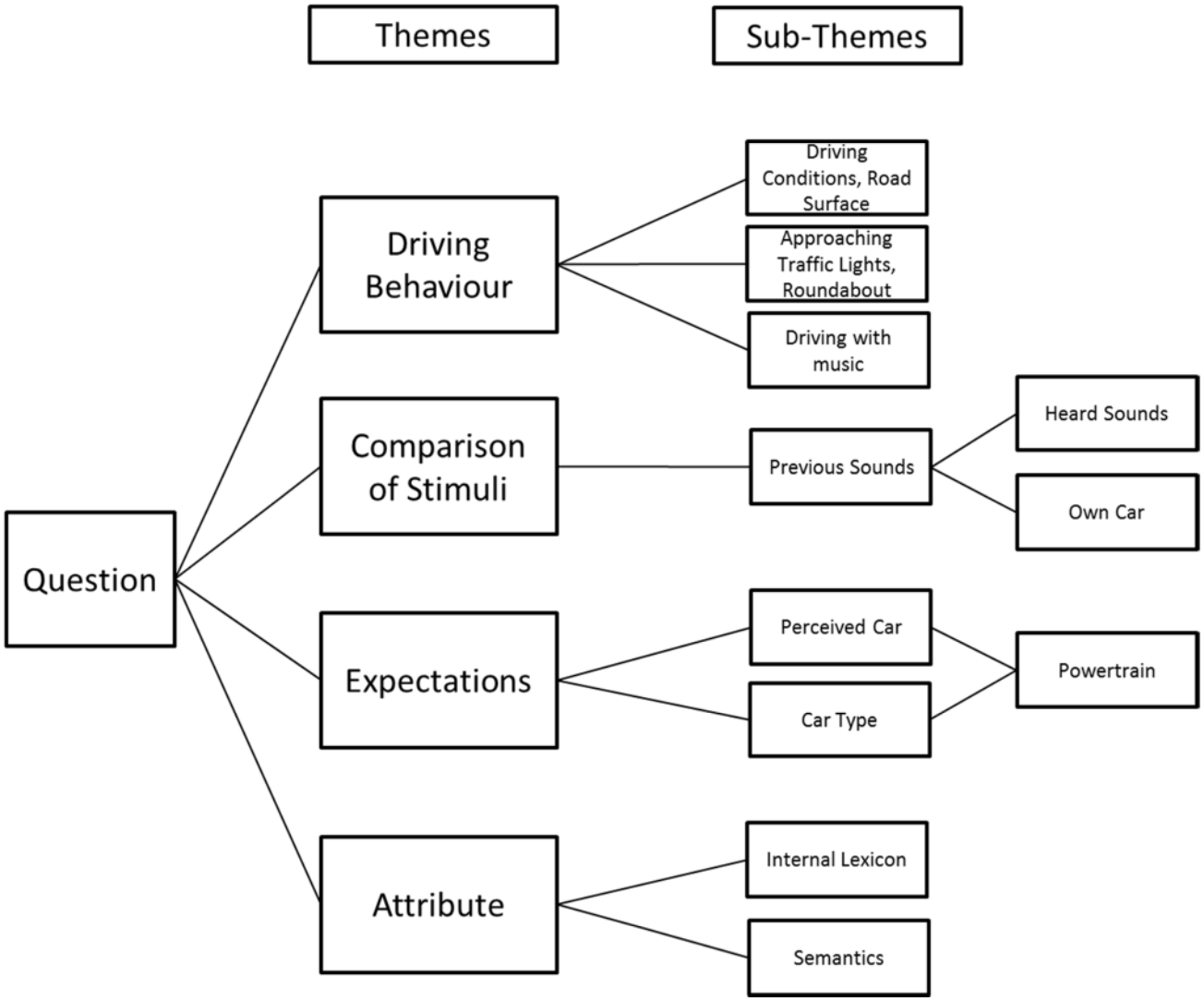
Prompt 1 – Explain it using your own words this time.

The next set of probes can be used if the participant is not expanding/elaborating on their decision making criteria.

Prompt 2 – Can you further explain what you meant?
Prompt 3 – What factors helped you make your decision?
Prompt 4 – What is the most important factor?

The following probes can be used to tell the participant to proceed to the next question/section

Probe 5 – Answer the question/s and proceed to the next question...
Probe 6 – Proceed to section/question...


Themes
Sub-Themes
Question
Driving Behaviour
Comparison of Stimuli
Expectations
Attribute
Driving Conditions, Road Surface
Approaching Traffic Lights, Roundabout
Driving with music
Previous Sounds
Heard Sounds
Own Car
Perceived Car
Car Type
Powertrain
Internal Lexicon
Semantics

Appendix C - Study 3

Consent and Briefing Forms

THE UNIVERSITY OF WARWICK

WMG Innovative Solutions

Briefing Sheet for Structured Evaluations

Thank you for your interest in my research which looks into the judgement and decision making processes which are involved when individuals evaluate vehicle features.

You have volunteered to take part in a study which is known as a Cognitive Interview. Cognitive Interviewing is a technique where participants are asked to talk about their thoughts and decision making processes regarding specific events or exercises.

This particular study is adapting a form of Cognitive Interviewing known as Verbal Protocol Analysis. This technique asks individuals to say their thoughts aloud as they experience them when going through an exercise, in this case the exercise is a vehicle evaluation using an Interactive Simulator.

You will be asked to take part in a test which is used by vehicle manufacturers and research institutes. You will be asked to verbalise and speak the thoughts that come to your mind as you progress through the study, as well as the evaluation criteria that you use to make your decisions.

I would like to emphasise that there are no right or wrong answers and the study is focusing on understanding how individuals evaluate vehicles features. So we do ask for you to be truthful and to act as you would normally, so that it is reflective of the real world. It is important that you verbalise your thoughts about HOW you made your judgement. Once you have completed the study, I will ask you questions about the judgement making criteria which you may have used in the test.

The session will be recorded to help transcribe the interview afterwards to make sure it is reflective and valid.

If you have any questions please let me know and make sure you have read and signed the consent form.

Mujthaba Ahtamad
3rd Year PhD Student.

Supervised by
Professor Jennings (WMG), Dr Cain (WMG) and Professor Lamberts (Dept of Psychology).

Participant No:

CONSENT FORM
Study 3: Understanding the Thought Processes Involved in Interactive Simulators
Name of Researcher: Mujthaba Ahtamad

Please tick the boxes if you agree.

1. I agree to take part in the above study. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time. ☐

3. I understand that the interview will be video/audio recorded and will be used for analysis. Mujthaba Ahtamad and his academic supervisors Professor Paul Jennings, Dr Rebecca Cain and Professor Koen Lamberts will have access to this. ☐

4. I confirm that I have read and understand the information sheet provided for the above study. I have had the opportunity to ask questions and have had these answered satisfactorily. ☐

Name of Participant: Date: Signature:

Camera Arrangement inside NVH Simulator

Debrief Sheet

About you and your driving

Vehicle Make _____ Model _____ Year _____ Are you the primary user? _____

Gender: _____ Age: _____ Marital Status: _____

How many people under the age of 20 currently live with you:

How long have you held a driving license? _____

Where do you do most of your driving? (Please split them up into approximate percentages into the following)

Motorway ..... City Centre/Town..... Country roads.....

Please rate how characteristic the following statements are of you.

Example Scale 1- I don't feel that way at all. 2- I don't necessarily feel that way 3-I don't care one way or the other. 4- I feel kind of like that. 5- That's exactly how I feel.

I like driving on challenging roads.....	☐	I will tolerate some problems if I get the performance.....	☐
Fuel economy is very important.....	☐	I would never buy a vehicle in the year it is released.....	☐
I want a vehicle that stands out from the crowd.....	☐	I tend to prefer vehicles that are larger.....	☐
I prefer an environmentally friendly vehicle.....	☐	To me, safety is more important than styling.....	☐
When I buy a vehicle I want the best in its class.....	☐	The brand name is very important.....	☐

Thank you

Thank you for completing the study. Your responses will be kept anonymous. This concludes the study.

If you are interested in taking part in future studies or hearing more about the research please provide us with your contact details.