Human Emotional Response to Automotive Steering Wheel Vibration: Development of a Driver Emotional Semantic Scale

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Abstract

The 21st century automobile has become more than just a simple tool for transportation and more of a brand image or a way for drivers to express their personal taste. This has made it increasingly important for automotive manufacturers to design the driver experience and driver feeling so as to tailor their preferences and interests. Currently there is not enough information on how to design or brand the communication of meaningful feedback from the automobile to the driver. With the development of new advanced technologies such as electric steer-by-wire systems or electric automobiles, the need to provide meaningful feedback to the driver plays a central role in the experience of using the new driving technology. Thus it is important to understand how to assess the emotional response to the stimuli reaching the driver so to be able to optimise at later stage the perceived experience. Steering wheel vibration feedback plays an important role for the driver's control input when driving. There is currently a lack of research on the formal assessment criteria of driver emotional response used to define automotive steering wheel vibration feedback, therefore this thesis proposes a newly Driver Emotional Semantic (DES) Scale to answer the research question: "*How can the emotional response to steering wheel vibration be assessed?*".

This study starts with a comparison of a questionnaire survey (Exp.1) and a laboratory test (Exp.2) to identify if a correlation exists between the emotional ratings measured from the expected driver's perception of the vibration and the experienced emotional feeling of steering wheel vibration. The work then defines a semantic scale to capture the vibrational vocabulary used by the driver to express their feeling of perceived vibration during real-road driving scenarios. Experiment 3 was therefore carried out to gather the underlying semantic descriptors used by drivers during driving scenarios. To test the reliability of the descriptive pairs of the DES rating scale developed, two evaluations of the assessment criteria were carried out: in real road scenarios (Exp.4) and laboratory test setting (Exp.5). Current research findings of this thesis suggest that the consistency of the scale dimensions found in the field study has captured with greater accuracy the driver semantic experience of automotive steering wheel vibration character as compared to the laboratory experiment dimensionality. Results suggest that the main vibrotactile semantic descriptors to assess the human emotional response to automotive steering wheel vibration were found to be four: pleasant, smooth, sharp and powerful.

The final proposed DES scale could help automotive research and industry determine and customise the aspects of the automobile towards drivers' preferences of felt experience.

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Acknowledgements

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Chapter 1 – Motivations behind the research

1.1 – The problem of automotive feedback

The 21st century automobile has become more than just a simple tool for transportation and more of a status symbol or a way for someone to express their personal taste. This has made it increasingly important for automotive manufacturers to fully design the overall experience for the driver and the passengers, but currently there is not enough research or information on how to design or brand this sensory feedback. The problem of the communication of information to the driver from automotive feedback started with NVH refinement and it's never ending trend of sound and vibration reduction within the automobile for participant comfort. More recently with the development of new advanced technologies such as electric steer-by-wire systems or full electrically propelled automobiles, the need to provide meaningful feedback to the driver plays a central role in the acceptance of using the new driving technology. In order to be able to design for sensory feedback, it is important to first understand how to evaluate or assess the emotional and perceptual characteristics of the stimuli reaching the driver, so to be able to optimise at later stage the perceived sensory experience.

Automotive research has traditionally considered drivers' emotional response mainly in terms of annoyance or discomfort elicited by the mechanical stimuli such as the sound and vibration produced by the automobile (Ajovalasit and Giacomin, 2007; Katu et al., 2003; Morioka, 1999; Parizet et al., 2008). While most of the research performed to date has mainly addressed the needs of reducing the intensity of the mechanical stimuli with the preconception that "less is better" (Lu, 2002), recent research in the field of user interfaces (van Erp and van Veen, 2004; Ho et al., 2007; Spence and Ho, 2008) has turned its attention to the study of multisensory emotional interfaces in which stimuli, mainly artificial, can be used to enhance efficiency in capturing attention and in producing fast and/or accurate responses from users so as to provide feedback about an action, alerts or warnings. However, mechanical signals can also provide important contextual information to the driver such as about a automobile or road condition (Giacomin and Woo, 2004; Berber et al., 2010) or in occasions capture and direct users' attention towards important events such as a failure in the engine. Mechanical signals can also contribute to the overall pleasantness of driving a car, since the sound and vibrations produced by the automobile are often associated to powerfulness, sportiness, luxury, reliability and comfort (Penne, 2004). For example the sound emitted by the automobiles door being closed, or the sound and vibrations emitted by the automotive engine may become an acoustic/ vibrotactile "footprint" of a specific brand that makes the product more attractive to the user, and thus can improve the driver's overall pleasantness and satisfaction (Lyon, 2000; Västfjäll, 2003). While a significant body of literature has analysed product sound quality (Blauert and Jekosch, 1997; Jennings et al., 2010) looking at the adequacy of sound stimuli in the context of a specific technical goal or task, little research has been performed to understand the human emotional response to automotive interior mechanical vibrations alone, which a driver feels through the seat, floor or steering wheel.

Automotive feedback is an important source of driver information, providing crucial stimulus about the characteristics of vehicle dynamics and the quality of the designed driver experience within the automobile. The perceptual multisensory feedback, which occur during various driving conditions, are fundamental towards understanding the cognitive and emotional engagement of the driver. All types of information can be perceived from the various sensory feedback encountered while driving, including gear change, parking distance, door central locking sound, fuel warning sound, tyre puncture, road condition, tyre skid, amongst many others. Several research studies have been carried out in order to identify ways to help automotive manufacturers understand the design characteristics of the feedback perceived, and to find ways to enhance driver awareness by using visual (Kim and Dey, 2009; Simon et al., 2009), auditory (Hurwitz and Wheatley, 2001; Shahab, 2010) and vibrotactile (Berber et al., 2010; Beruscha, 2011) feedback for improving driver safety.

In addition to communicating important vehicle and environmental information to the driver, automotive feedback is also be used to design and enhance the perception quality and brand identity of the automobile experience. Customer demands are satisfied when a product design leads to a harmonic perceptual entity (Altinsoy and Jekosch, 2012). This satisfaction is the case when the perceived form of the product and the function it conveys are coherent. The quality evaluation of vehicle sounds and vibrations is a complex process. Physical measures are insufficient to describe and understand this process and can only provide superficial cues. Quality evaluations by automobile customers are based on their perceptions, emotions, interpretations and expectations. The perceived quality of idling sounds and vibrations is an interesting subject in vehicle acoustics because sounds and vibrations consist of mixtures of stationary and non-stationary signal components. In evaluating automotive sound quality, there arises the need to identify and elicit the relevant attributes, which are the dimensions of the perceived quality.

The evaluation criteria of an automobile's sensory characteristics/ features and the driver's perceived reactions to these stimuli can be of great importance to automotive manufacturers, so determining the design criteria of the semantic language of automotive feedback could be the key to developing a unique and desirable brand DNA and communication characteristics. The perceived quality of a brand and usability of a product, the comfort when using it, as well as its effectiveness, can all depend on the nature and intensity of the emotional experience perceived from the feedback. The driver perception of the brand quality, comfort and emotional characteristics have been identified in numerous automotive market research studies (Autotrader, 2013; J.D. Power, 2014), including studies identifying the emotional motivators for automotive consumer purchasing criteria (Trend Tracker, 2011; Nielsen, 2014). The emotional attachments or the driver emotional response is becoming a key design aspect in today's 21st

century automobile, as enhanced and coherent designed brand experiences can act as great motivators for purchase decisions and customer satisfaction. To enhance the perception of an automotive brand's sound quality a great importance has been placed on the design of automotive auditory feedback studies, which look at the perceived quality characteristics of the various aspects of the automobile in relation to the perceived emotional attributes, such as the quality attributes of the sound from the engine (Kubo et al., 2004), the power window (Zhang et al., 1996), or the automobile door closing sound (Parizer et al.,2008). Within all of these studies including many others, it is becoming increasingly evident on how important it is to categorise the communication patterns and the semantic attributes drivers associate to certain types of feedback in order to help the automotive manufacturers to better design and address the overall experience and the emotional reactions felt when driving an automobile.

Although there is an agreed consensus on the importance of the numerous sources of multisensory feedback (vision, vibration, sound and smell) within the automobile as presented in Figure 1.1, there is also growing evidence that today's vehicle refinement targets and driver cabin noise control developments have significantly reduced the sensory feedback within the automobile.

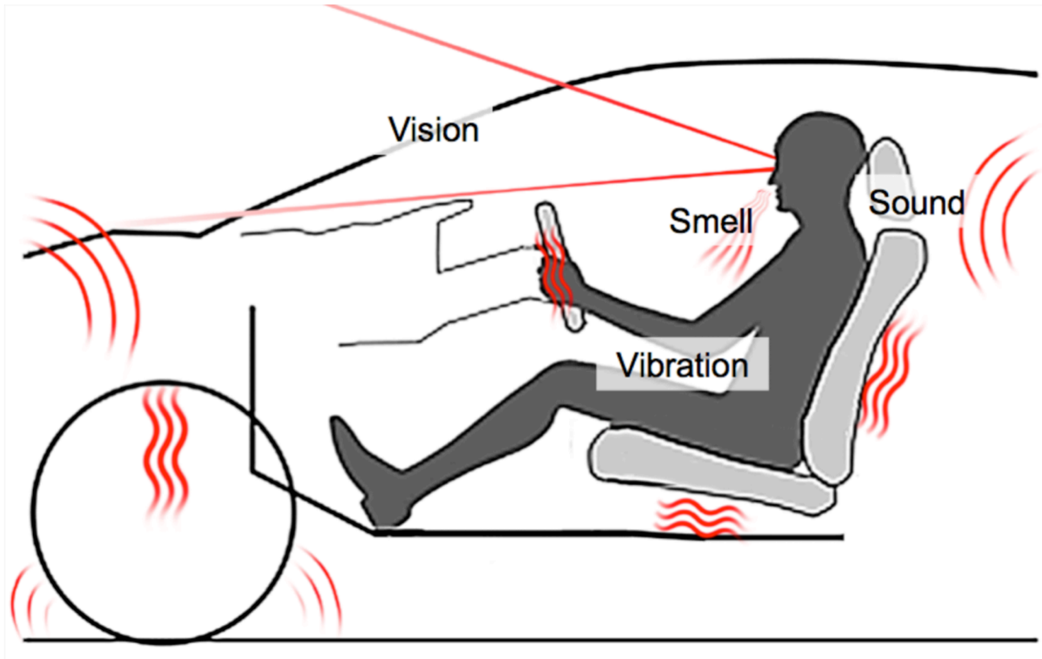


Figure 1.1 *Automotive sources of Multisensory feedback*

Comparisons tests with drivers of modern automobiles and drivers of older generation automobiles showed (Walker et al., 2007) that there has been a significant decrease of automotive sensory feedback in the last 15 years, considerably reducing the driver situation awareness of the vehicle. Walker's study extracted so called 'knowledge objects' (aspects of the driving experience that the participant is aware of) during driving studies of new and old vehicles and concluded that the perception of them is significantly reduced for drivers of modern cars. Other research has highlighted the importance of how one sensory modality can affect another by showing (Horswill and Plooyô, 2008) that even a small change of the auditory feedback can alter the driver's perception of motion, potentially encouraging faster driving and increasing their levels of risk to cause accidents. This mismatch between the driver's perceived experience and the automotive feedback stimuli is widening the communication gap between driver-automobile interaction (Loasby, 1995; Norman, 1990), making for weaker product attachments. One of the main challenges caused by the decreased feedback is the lack of emotional engagement during the driving condition. Although being crucial to the driver experience, emotional events have the capability to interrupt on going cognitive processes and automatically grab driver attention, eliciting an attentional or behavioural switch towards these events (Öhman, 1993; Phelps et al., 2006). The design of emotional responses in an automobile are crucial to consider also due to the fact that the driving task is a highly demanding process which can be greatly affected by slight changed in drivers mood, signifying the importance for a well designed driver experience.

The perception of the driver experience is comprised of vision, vibration, sound and smell and it is often challenging to single out one sensory feedback without affecting perception as a whole. The 21st century automobile has developed into a fully designed or tailored driving experience this is especially the case for the executive or luxury range of the automotive sector. With designers looking into new ways to customise and enhance various aspects of the automobile such as muffler noise, drivetrain (comfort, sport or eco) feel settings, warning sounds, material textures, door closing sound, etc. These techniques are widely used in the industry to tailor the perceived brand identity or the product quality of the automotive segment.

Hence, in order to enable automotive manufacturers to tailor and enhance the sensory feedback within an automobile, it is important to first identify the driver's vocabulary and the emotional semantic attributes used to describe the perceived feedback stimuli, so as to categorise the descriptive dimensions necessary to measure when developing and refining an automobile's systems for eliciting a chosen driver experience.

1.2 – Automotive Noise Vibration Harshness (NVH)

Noise, vibration and harshness (NVH), is a common term used in the assessment and modification of the noise and vibration characteristics of automobiles. Whilst the noise and vibration are measured objectively using recording equipment, the harshness is measured subjectively using methods such as jury evaluations or other analytical techniques. Traditionally NVH was mainly focused on the reduction and isolation of the noise and vibration feedback within an automobile cabin. Whereas recently more studies are being carried out which change or enhance the quality of the sound or vibration quality by increasing or decreasing parts of the stimuli characteristics.

The noise within an automobile cabin is mainly caused by various airborne and structural-borne paths from the engine, driveline, tire contact patch and road surface, brakes, and wind, whilst the vibrations is sensed through the steering wheel, seat, gearstick, pedals and floor. Because it is constantly in close touch of the naked hand, without much inhibiting or dulling sensation such as through clothing, the steering wheel is especially important in NVH.

Automotive designers have a difficult challenge in moderating NVH because the source is not located in one place, rather it is generated from a wide range and combination of mechanical parts. Moderating noise and vibration in vehicles has been seen as key for development, in terms of legal issues and demands of the market For example, increasing environmental impact awareness has meant that there is increasing pressure to moderate and reduce emissions from a legal standpoint. From a marketing standpoint the growing competition between brands and manufacturers means that satisfying customer needs in terms of the thrill or luxury of their experience.

The market consistently expects improvements on vehicle models, in return for their custom and loyalty. The expectations are that a new model will offer more comfort and better performance than their last, this is distinguished significantly by the driving experience. Even if a new model vehicle has been developed and improved in every way, compared to the previous model, it will not feel like it to the customer, in other words if they can’t feel the difference then they won’t trust or accept the manufacturer’s word for it. Most drivers aren’t familiar enough with the mechanical engineering of a vehicle, to distinguish what improvements have been made, so they rely on their sensory feedback, influenced by their emotion and attention.

Improvements of NVH in vehicles are, therefore, in aid of: improving/ maintaining a brand image, improving comfort of experience, improving quality of experience, and reducing costs.

The assessment of NVH, in order to design improvements, is concerned with suppressing each element and moderating it to the established desirable state. The process includes:

- Establishing benchmarks
- Establishing targets
- Design
- Prototypes
- Testing
- Qualifying
- Development
- Diagnostics of new design
- Revised solutions

1.2.1 – Vehicle Refinement of NVH

The development of new technology and materials available has allowed NVH engineers to use creative new ways to uphold the brand character or the perceived quality of an automobile's characteristics such as the feel of the clicking from the specially crafted automatic gear shifter of the Pagani Huayra (Ford, 2012) or the adjustable exhaust muffler sound from a Bentley Continental (Senapati and Jackson, 2013), which adjusts the sound quality through the exhaust airflow from its variable displacement technology engine that allows it's V8 to operate as a V4 during light load conditions. The automotive steering wheel is also taking shape in today's luxury market, as many manufacturers are aiming to provide in addition to other components, customisable steering vibration feedback which will adapt according to the specified driving preference such as the ride mode switch or the Ferrari Manettino switch (Calvosa and Visconti, 2008).

One crucial issue also facing automotive manufacturers today is that the introduction of electric automobiles and electric assisted systems, a lot of the driver feedback is being lost due to the change in the powertrain and the absence of direct connecting shafts and other structural-born parts. With regulations already being put in place, which required electric automobiles to make an artificial sound in addition to the electric motor in order to make them louder so that their distance can be perceived by visually impaired pedestrians. The effect of the electronic advances are also becoming evident in the steer by wire systems which highly impact the steering wheel vibration feedback. Automotive companies are also considering implementing the vibratory feedback artificially, but currently there is a lack of knowledge on the guidelines for how to best represent the vibrotactile language or the sensory design specifications to best represent their brand and product aim. This is done by replicating the stimuli at the wheel using accelerometers and shakers, but the lack of knowledge on the potential of informative features of the vibrations means that most design characteristics so far have been basic.

1.2.2 – Automotive Steering Wheel Vibration

When considering what kind of feedback and information drivers need to perceive within the automobile, the steering system has always been acknowledged as a system with great potential for providing useful information to enhance driver safety (Honeywill, 2008; Ito and Kamata, 2010). Compared to auditory feedback, drivers are more responsive to vibrotactile cues such as steering wheel vibration or feedback stimuli resisting the driver's control input (Schumann et al.,1993).

Of the car/driver interfaces, the steering wheel (Pak et al., 1991) is also a fundamental subsystem due to the sensitivity of the skin tactile receptors of the hand (Bolanowski and Gescheider, 1988) and due to the lack of intermediate structures such as shoes and clothing which can act to attenuate vibration stimuli. Between the two constant hand operated controls (steering wheel and gear stick) the information perceived from them if different, where the gear stick will produce mechanical vibration communicating the condition of the transmission system, the steering wheel will produce vibrations from road surface conditions and tyre dynamic data. Automotive vibration is oscillatory motion, and its perceptual response is determined by many factors including the characteristics of the motion, the characteristics of the exposed driver, the activities of the exposed driver and other environmental aspects. The magnitude of the vibration is determined by the extent of the oscillation and the frequency of the vibration is determined by the repetition rate of the cycles of the oscillation (Griffin, 1990).

Noise, vibration and harshness (NVH) research has played an important role to the design of modern vehicles, as traditionally the trend of reducing both auditory and vibratory feedback has been the main aim for a long time. Although steering wheel vibrations are considered a source of minor discomfort (Amman et al., 2005; Giacomin et al., 2004; Griffin, 2007), recently the benefits of these vibrations have been explored in different studies suggesting their importance as a vital source of driver feedback (Giacomin and Woo, 2004; Walker et al., 2007).

The assessment of steering wheel vibration stimuli were also chosen based on the fact the steering vibration should be mainly caused by the act of driving over a road surface. This was decided based on the results of a previous questionnaire study (Giacomin and Gnanasekaran, 2005; Berber-Solano et al.,2010), which suggested that the respondents considered steering wheel vibration to be particularly useful towards the detection task of determining the road surface type.

The advancement of automotive technology is moving towards more intelligent electrical driving systems, which allow the vehicle drive to be more intuitive and to allow for better understanding of the automobile dynamics and the driving environment. The conventional steering system is also an important part, which is being replaced by an electronic drive by wire systems. A layout of both conventional steering system as well as the new steer by wire system is presented in figure 1.2.

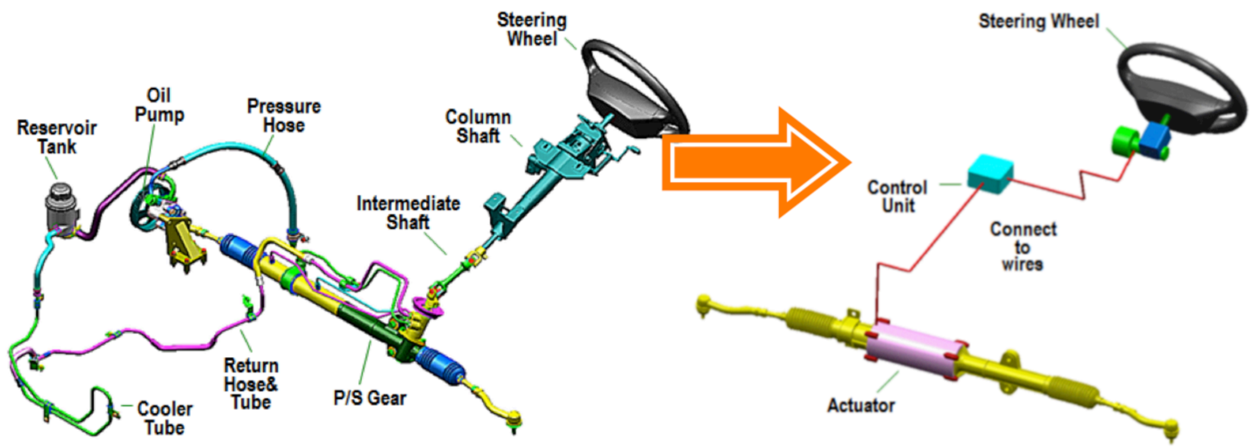


Figure 1.2 *Conventional Automotive Steering System & Electric Drive-by-Wire Steering System*

This modification would remove the steering column, which is a vital part for transmitting vibration feedback, in return allowing the vehicle steering to be electronically overridden and controlled in hazardous situations. The development of this technological advancement has opened opportunities for research based on the simulated feedback the driver needs to receive through the steering wheel as this tactile stimulus will have to be artificially produced within the new drive-by-wire steering systems.

1.2.3 – Advances in Automotive Steering Systems

While the vibrations through the steering wheel system in motion can go up to 300Hz (Giacomin et al., 2004) with vibration types affected through the column as well as the wheel sometimes resulting in peaks between 20 and 50 Hz (Pottinger et al., 1986). The primary focus of studies in the field are concerned with how steering wheel vibration results in discomfort for the driver, specifically the way the individual will respond to the sensitivity of the hand-arm to vibration experience and the way it can be seen to cause fatigue. There are fewer studies available on the type of information or semantic language interpreted by the driver through the steering wheel feedback.

This study aims not to ask ‘how much discomfort or harshness do vibrations cause to drivers?’ but rather, ‘**what vocabulary do drivers use to describe the vibrotactile feedback’** of automotive steering wheel vibration and how this vocabulary can be defined into the main assessment criteria for evaluating the emotional response to automotive steering wheel vibration feedback.

1.2.4 – Benchmarking and Target Setting of Automotive NVH

Automobile characteristics selected as benchmarks are evaluated according to their style, price, weight, and target market Tests are conducted both during motion and without motion, distracting noises like rattles, tone, noise of the road, the auxiliary, and gears. Further, benchmarks are considered by the rate of acceleration as well as the consistent speed. Both interior and exterior noise is evaluated, with an aim of reducing it.

It is important that vehicles are developed with subjective analysis in mind, since the requirements for improved change depend on how the driver feels. This qualitative research is critical in gauging and understanding the emotional response to NVH, in order to analyse this alongside gauges of physical impact. In other words research on driver experience needs to take into account what the driver feels physically as well as how that makes them feel emotionally. Further, alongside subjective and objective analyses it is important that tests are conducted on vehicle models to set targets to derive the best example for comparison.

Setting targets is necessary to understand what the design needs are, these are established based on the benchmark research and represent a combination of best-in-class examples of manufacturing and the range of emotional experience elicited by the driver. By looking at the desires of the customer it is possible to choose vehicles for comparison, as benchmarks. These benchmark vehicles, considered the best, can then be analysed for their systems and specifications to derive targets. The importance of measuring methods and the criteria assessed is crucial for identifying and developing the benchmarking and the target setting.

1.3 – The 21st Century Automobile

Descending from different fields or research such as ergonomics, computer science and branding, the use of human centred design as an innovation process has been an increasing choice of research strategy for many companies. Giacomin (2012a) has provided a detailed review of the economic and developmental benefits that could be achieved by adopting human centred design as a business strategy as it can develop products, systems and services with significant importance applied to the user's perception, interaction, learning and meaning. With great emphasis applied to the metaphysical meanings in which we construct, based on our interactions and relationships with systems, products or services. Human Centred Design is the umbrella paradigm (figure 1.3) that covers a wider range of key design consideration for systems products and services combined using a holistic approach to human interaction. Not only does this model of the Human Centred Design pyramid cover the essential contributors of the relationship between design artefact and the user, but it is also structured in a hierarchical form, which conveys the growing levels of complexity of its approach.

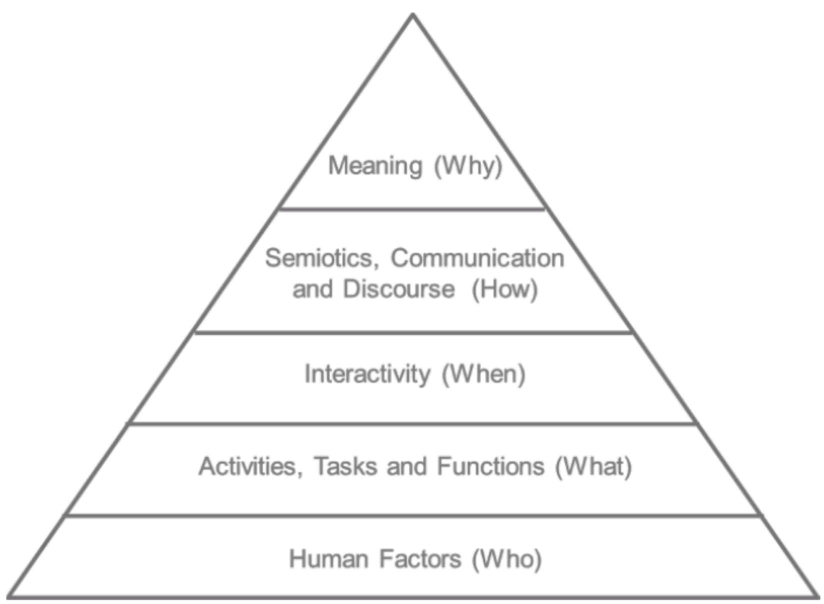


Figure 1.3 *The Human Centred Design Pyramid.*

The great opportunities available to the industry for perceptually enhancing the vibration language of the feedback perceived through the steering system has been acknowledged in recent studies (Ajovalasit et al., 2013; Giacomin, 2012b), which identify the communication and information carrying potential of the steering wheel vibrations perceived. This is especially the case for new steer-by-wire technologies, which due to the lack of vibration feedback will have to include systems that artificially implement this enhanced perceptual cognitive and meaningful information as to enhance sensory branding, driver behaviour, and emotional responses.

Although driver comfort is an evident goal for the benchmarking of design targets, it is of upmost importance that the driver's comfort is well balanced with informative stimuli to allow for a better-improved driver-vehicle relationship/interaction. To address this matter the Perception Enhancement Research Group within Brunel University has proposed a perception enhancement system to be included in drive by wire steering systems, presented in figure 1.4.

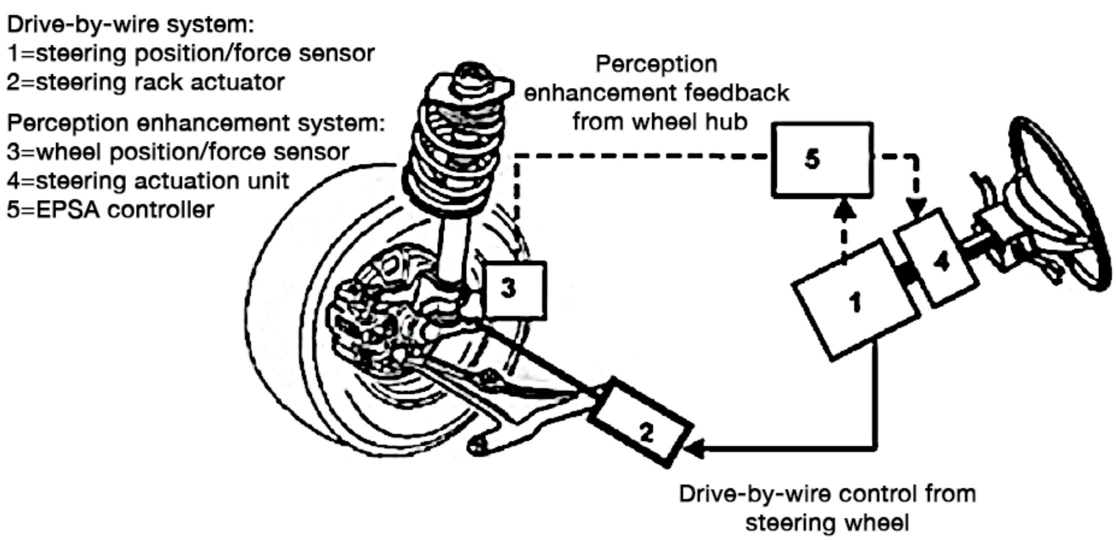


Figure 1.4 *A perception enhancement system for drive by wire steering*

The systems main function is to identify and analyse the characteristics of the real time stimuli transferred from the wheel hub, then to manipulate the data in order to enhance feedback detection and driver awareness while at the same time keeping a well set balance between driver comfort and information content within the feedback.

Figure 1.5 shows a schematic of the paths of objectives and how the Perception Enhancement Research group aim to balance these two vital considerations of automotive feedback. The schematic figure emphasizes the importance of balance between the vibration stimuli content, the subjective measure of comfort from the stimuli and the measure of cognitively relevant information features.

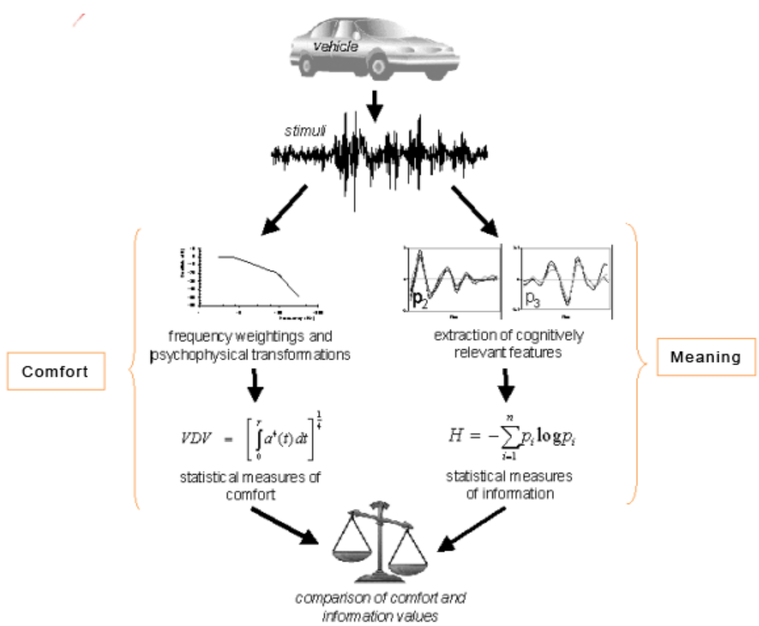


Figure 1.5 *A Perception Enhancement System Approach to Comfort and Meaning*

Perception enhancement is derived from the human centred design approach which improves human well-being and empowers people through the development of systems, machines, products, services and processes which are physically, perceptually, cognitively and emotionally intuitive to use (Giacomin, 2012a). Advances of the automotive industry have progressed mainly due to the technological and environmentally sustainable innovations carried out, with limited importance applied towards the human centred design approach. While the psychophysics of the human subjective response to hand-arm vibration is relatively well understood in terms of properties such as the amplitude response, the frequency response, and masking effects, less is known about the factors influencing the human emotional response to the vibration which a driver feels through the steering wheel. The research gathered so far has allowed the Perception Enhancement Research team to build a database of general understanding of the stimuli from steering wheel vibrations and their characteristics affecting driver perception. Although so far a vast amount of research has been done to translate and understand the vibratory stimuli perceived through the hand, a less understood area of vibration perception is the connection factor of how the tactile stimulus affects the driver emotionally. This is to target and identify the core cognitive feelings that driver's perceive from the road stimuli.

1.4 – An Approach to define the Emotional Framework of this Study

It is evident that the transition path from the source of automotive vibrational stimuli up to driver perception involves a complicated structure, as there are various aspects of influence that affect the overall driving experience. Using the review of the available literature in the previous chapters, a visual framework of emotional experience was constructed (Figure 1.6) to clarify and visualise this overall transition path. The framework is built in two parts, one the physiological transition path of the stimuli and two cognitive transition path of the perception of the stimuli. The first path of the actual vibration from the haptic source up to the driver's sensory receptors is quiet straight forward, as the driver experiences haptic stimulus through the five main body contact points which is perceived by hand sensory receptors. The second part of the framework on the other hand is more complex and includes the influential cognitive processes that the driver goes through to experience the perceived vibratory stimulus. The second part of the framework is based on the cognitive transition process which is a subjective process, as it depends on the driver's personal characteristics, whether the surrounding factors will emotionally affect the driver or not. When the sensory receptors perceive the vibratory stimuli, cognitive processes come into play, then when the driver appraises whether the felt stimuli is of significance to his or her wellbeing, the perceived stimuli communicates an emotional response. Other factors affecting the emotional experience include aesthetic interpretation, previous experience, the perception of affective quality, other sensory stimuli perceived and the core emotional affect as described by Russell (1980). Although the emotional framework shows only the transition of vibratory stimuli affecting the driver, the overall influential factors could always be expanded upon with other perceived stimuli, as the haptic feedback is only one part of the overall perception within the driving experience. This framework is compiled to help visualise an understanding of the current knowledge based on the affected factors of vibration feedback.

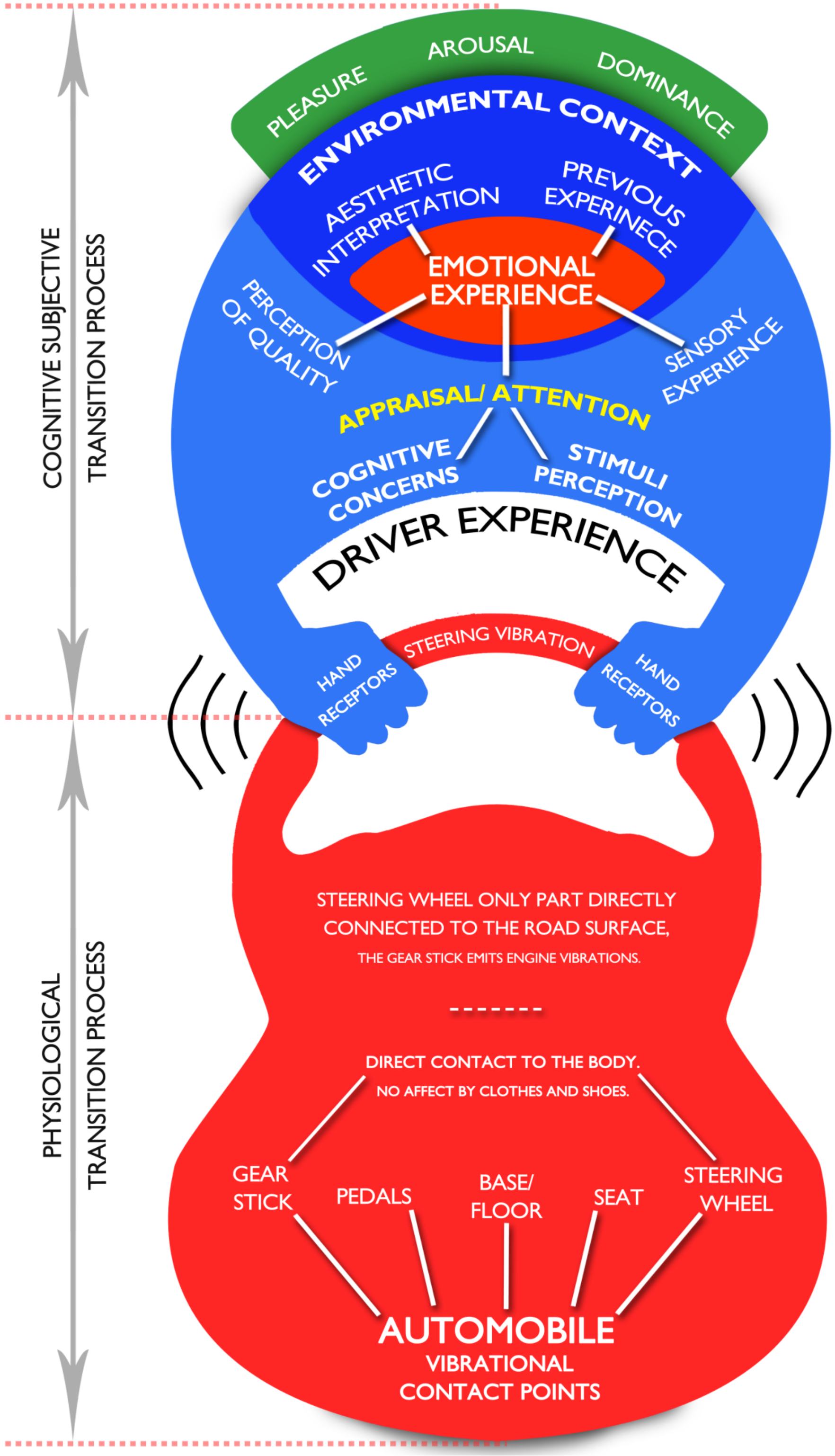


Figure 1.6 *A framework of vibrotactile feedback and its transition path to driver perception used for this study.*

Built from the review of the current literature, the format uses a simple linear direction and easy to follow visuals to collate the various research findings gathered based on the emotional response of vibrotactile stimuli. The graphical emotional framework of the transition path of haptic stimuli perception was constructed to clarify the overall process and the influential factors that are fundamental to the building blocks of the driver's emotional experience. As hand sensory receptors are best for perceiving informative stimulus, and the steering wheel is the best contact point, emitting direct vibrations from the road surface condition, this characteristic has been highlighted within the framework. It is evident that the overall emotional experience is subjective to many various factors many of which are highlighted within the framework.

Although the framework features many aspects of the driver's emotional perception, not all factors may be affected at the same time, as this depends on the characteristics of the driver's personality and emotional state. As well as being used to understand the transition path of haptic stimuli, this model could also be used to pinpoint and target an exact area aimed for improvement, to be able to achieve an enhanced balance of driver comfort and informative tactile feedback that is passed through steering wheel contact points to achieve a greater overall emotional response.

1.5 – Research Objectives

Based on the literature review performed, there is a lack of research and understanding on how to measure and describe the driver's felt experience and emotional response to the automotive vibration stimuli so as to attune the behaviour of the automobile to the desired driver's expectations of its performance during driving scenarios. The main research question being addressed by this thesis was:

"How can the driver emotional response to steering wheel vibration be assessed?"

This study aims therefore to set a methodology to measure and assess the human emotional response to automotive steering wheel vibration from road surface acceleration stimuli, focusing on identifying the key semantic descriptors that can be used as assessment criteria to characterise the driver's emotional response to automotive steering wheel vibration during driving scenarios.

The following objectives were carried out in order to answer the research question:

1: To understand how emotions affect the overall driver experience and behaviour within the context of automotive driving scenarios. (Chapter 2)

2. To review the current methods used to assess the human emotional response and the semantic descriptors currently available. (Chapter 3)

3. To assess the driver's **expected** emotional response to steering wheel vibration as recalled from their long-term memory and past experience of typical driving scenarios on different road surface types by means of the existing valence and the arousal criteria. (Chapter 4 - Exp 1)

4. To assess the driver's **experienced** emotional response to steering wheel vibration as felt through a steering wheel test rig setup along the valence and arousal dimensions, and to compare with the expected responses. (Chapter 4 - Exp 2)

5: To collect, extract and select the **driver's semantic vocabulary** so as to define a rating scale to assess the human emotional response to steering wheel vibration stimuli in automobiles. (Chapter 5 - Exp 3)

6: To assess the reliability of the driver emotional semantic scale when it is applied in real road driving scenarios (Chapter 6 - Exp 4)

7: To verify the reliability of the driver emotional semantic scale when it is applied in laboratory based setting (Chapter 7 - Exp 5)

In order to better define and visualise the research objectives of this thesis, a development plan was used, which included each of the seven research objectives, as well as additional details of what each objective involved. Figure 1.7, presents the proposed research development plan, which shows that each objective defined has been colour coded, and all seven of the objectives have been split up into three main project phases.

The first two research objectives (1+2) are addressed in the first phase of the study, which was planned in order to carry out a review of the current literature available on automotive driver experience, behaviour and the cognitive processes involved during the driving task as well as emotions and the current measuring techniques.

The second phase of this research involved the first two preliminary experiments carried out to assess the driver's expected emotional response and the driver's experienced emotional response to steering wheel vibration of different road surface types by means of the existing valence and the arousal criteria.

Finally the third phase started to define and develop the driver semantic vocabulary of vibration and to evaluate the descriptors gathered by identifying the dimensionality between the emotional rating of the automotive steering wheel vibration from different road surface types as driven by multiple automotive segments.

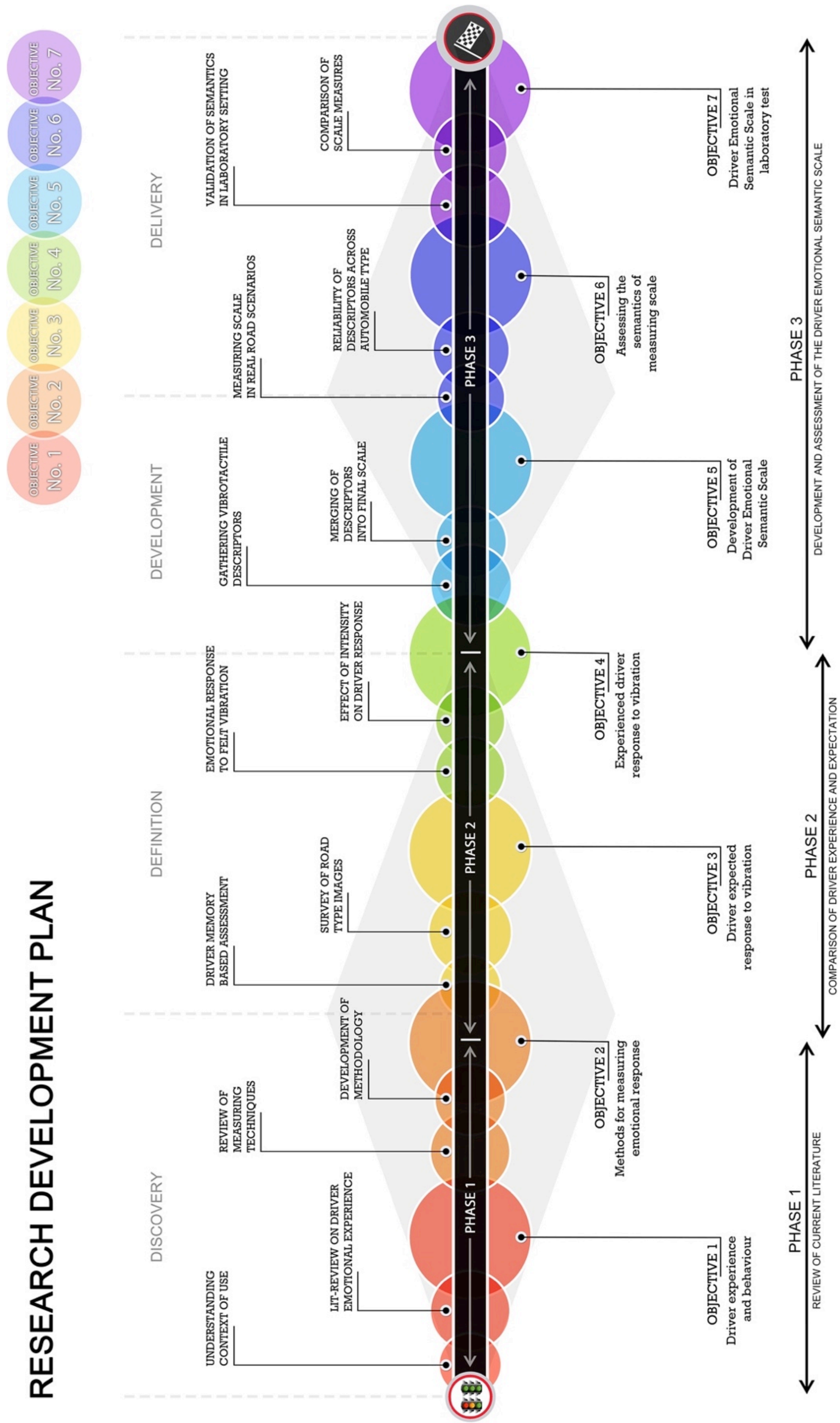


Figure 1.7 *Research Development Plan*

The main questions that the research set out to answer are the following:

a) Are there any differences between the expected emotional ratings obtained from the information recalled from the driver's long-term memory and the experienced emotional ratings obtained from the felt experience when holding a vibrating steering wheel?

b) How does the vibration stimuli intensity affect the emotional response of the valence and the arousal dimension?

c) What are the main vibrotactile semantic descriptors that can be used to assess the human emotional response to automotive steering wheel vibration in a real driving scenario?

d) Are the identified vibrotactile semantic descriptors reliable when used in real road scenarios?

e) Are the identified vibrotactile semantic descriptors consistent when used in a laboratory test setting?

Considering the significant need to identify the measurement criteria of automotive steering wheel vibration feedback, and the objectives set for the study, the questions aimed to be addressed by this research thesis were further defined to give a better understanding of the process carried out and the transition path of each experiment. Figure 1.8 shows each of the research questions defined and the expected deliverables of all questions, as well as the chosen experimental test method planned for each, which includes one questionnaire survey, two laboratory experiments and two field studies. The figure also includes the details of which chapter aims to answer each question.

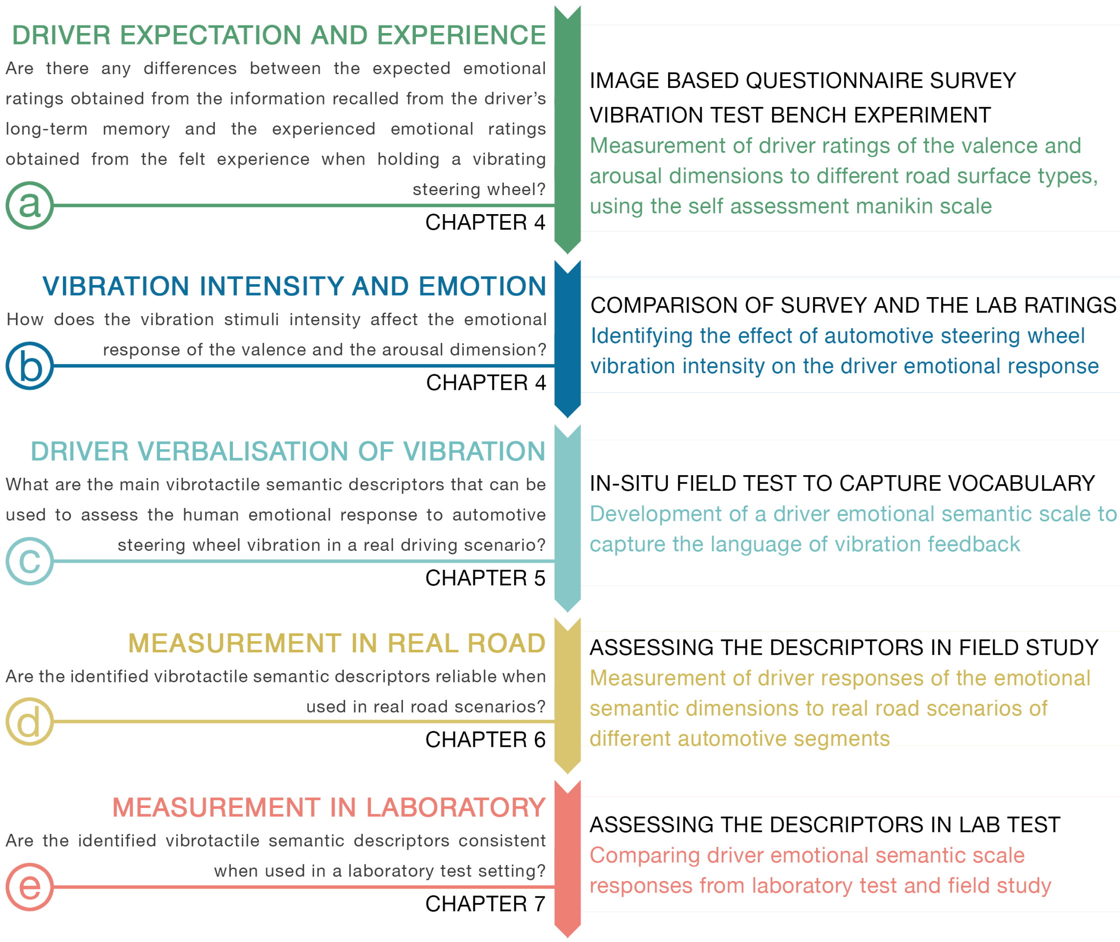


***Figure 1.8** Each research question defined and the experimental methods planned to answer them.*

1.6 – Contributions to Knowledge

Research shows that there is a significant gap in the knowledge into the understanding and assessment of the communication patterns and overall experience exchanged between the driver and the automotive steering wheel by means of the vibration stimuli. By adopting a human centred design approach to the automobile scenario as a business strategy it can develop products, systems and services with significant importance applied to the user's perception, interaction, learning and meaning of the felt experience. By identifying the optimal semantic descriptors that can describe the felt driver experience during driving conditions it is then possible to address the desired experience so as to help customise the aspects of the automobile towards a specific brand quality or product characteristics. This research contributed therefore to the understanding of the emotional semantic descriptors that drivers typically use to describe their felt experience to automotive steering wheel vibration.

A driver emotional semantic (DES) scale was developed in this work using the gathered descriptors, which is thought to be beneficial to different departments of the automotive industry to enable them addressing aspects of sensory branding and a tailored vibrotactile driver's response. The use of the DES scale can be applied during different design stages including: market benchmarking and target setting, new product development, Noise Vibration and Harshness (NVH) refinement, brand development and also post manufacturing quality testing. This research also takes the first steps towards evaluating the reliability of the DES scale in two different experimental test methods, one based on field test and one in a laboratory setting.

Chapter 2 - Driver Experience and Behaviour

2.1 – Driver Emotional Experience

Driving is considered to be 10% physical and 90% mental, it is within this mental cognitive process where emotional experience play an important role in evaluating the situation ahead and helping to ensure that the right action is taken. It requires a variety of human resources for continuous multiple body manoeuvres at the same time focusing on the exterior surroundings. To achieve the best driving experience individuals must simultaneously balance their emotional, physical and cognitive processes for a better driving experience. The same cognitive processes that tend to affect product emotional experience will affect user experience in driving situations with increasing factors like the exterior conditions, traffic, other road users, etc.

The importance of exterior context was highlighted by Gomez (2005), where he described the basic fundamentals of the overall driving experience. A schematic of the proposed framework is shown in figure 2.1, which emphasizes the importance of collaboration between human and artefact in combination with the anticipated activity/intention within the environmental context. He also suggests that if no consideration is applied to environmental context then the reported experience of the activity can be misleading. In order to perceive a more relaxed and intuitive drive the driver must feel comfortable emotionally, physically and mentally.

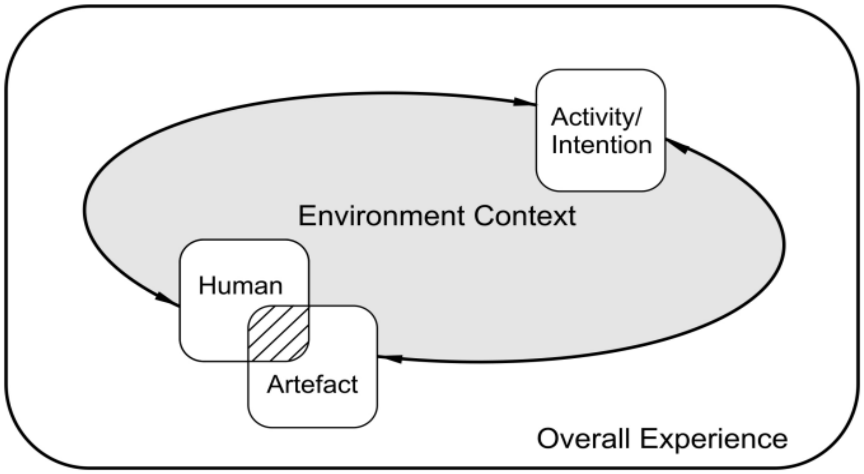


Figure 2.1 *Human-Artefact-Activity within context forms an overall experience (Gomez et al.,2005).*

Oborne (1978) looked at the connection between the vehicle passenger and the comfort perceived. He explained how passenger comfort is a subjective response and will depend on the individuals personality and of course their past and present experience. Oborne goes on to explain Mayr's (1959) terminology based on 'travelling comfort' which includes three sub factors of Riding comfort, Local comfort and organisational comfort. As this model was based on all public transport only ride comfort can be applied to automobile drivers as local and organisational comfort address aspects of public transport like comfort at stations or frequency or reliability of service. Mayr constructed a model for Ride comfort (Figure 2.2) to further explanation the significant interrelationships of comfort affecting factors within the vehicle. As the image shows he included psychological, physiological, subjective and technical/structural influencing factors.

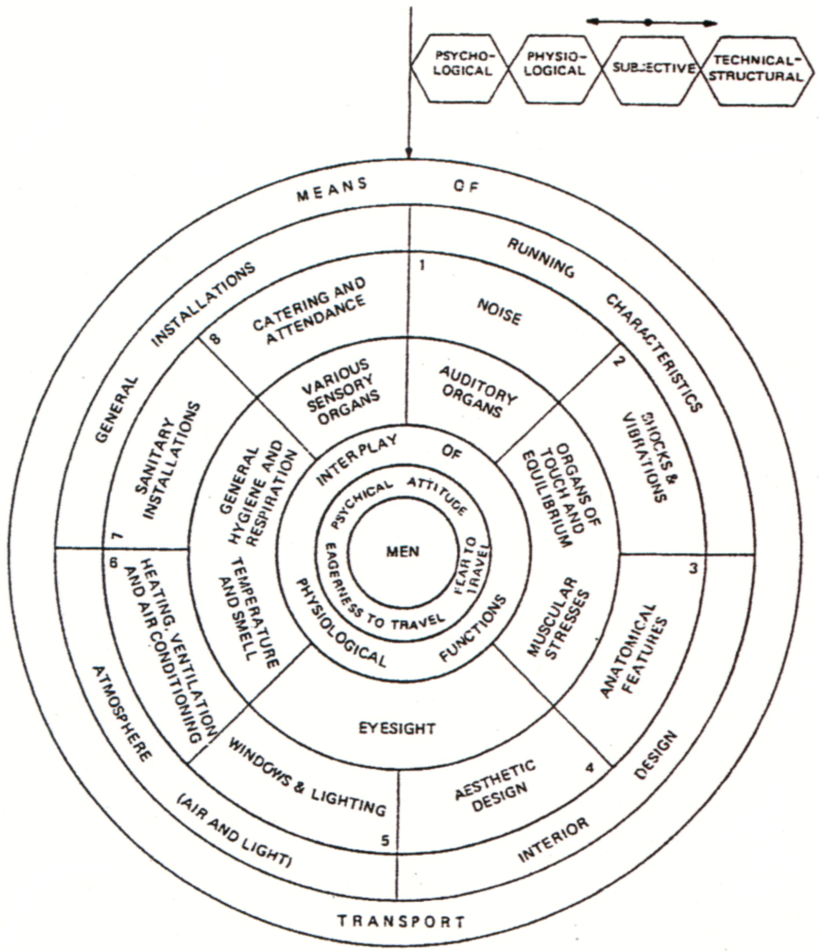


Figure 2.2 *Mayr's circle of riding comfort (Mayr, 1959).*

As can be seen from the model presented in figure 2.2, the position of subjective aspects is ordered by importance, which shocks and vibrations comes in second after noise and before anatomical features and aesthetics.

Giacomin and Woo (2004) investigated the more specific cognitive tasks of the driver from perceived steering wheel stimuli in order to understand the haptic feedback in order to identify and amplify the important informative vibratory feedback. The suggested cognitive driving tasks are Perception, Attention, Memory, Thinking/ Decision Making, Problem Solving and Language.

Compared to Demset's (2007) model of product experience the three vital components within (stimulus, appraisal and concern) could be associated with the first three cognitive steps proposed (Perception, Attention and Memory) by Giacomin and Woo (2004).

2.2 – Driver Quality and Comfort

People are spending longer in their cars, so quality and comfort is becoming even more important aspect. The increase in demand alongside marketing efforts from manufacturers has made differentiation pivotal to selling to and retaining consumers. When researching the level of quality and comfort experienced by people it is important to accept that the assessment will vary from person to person, but there is a set of variables that can reliably gauge the levels. Da Silva (2002) offers that comfort can be gauged by 'dynamic factors, related to vibration, shocks, and acceleration; [and] ambient factors, where thermal comfort, air quality, noise, pressure gradients'. Da Silva also explains that in automotive design the first thing to consider is which stimulus result in a negative experience for the driver, or to cause discomfort. Considering these stimuli requires a focus on the physical constraints, human sensitivity and intentional variables designed in cars.

Vibrations are considered in terms of the effect on the body, addressing specifically how the body reacts to oscillation in relation to its situation. It is measured by a body feeling sudden acceleration in relation to how that moment corresponds to that signal. Katrin Strandemar's study *On Objective Measures for Ride Comfort Evaluation* (2005) addresses two main focuses in understanding driver quality and comfort, 'subjective information from test drivers and measured vehicle properties'. Strandemar offers necessary definitions of ride, ride quality and comfort, the first of which relates to quantifiable environments incurring movement, such as vibrations, shock and acceleration. Ride quality relates to how far the subjective experience, within the Ride factors, are seen as eliciting a positive experience by the driver, and comfort relates to the well-being of the driver in an environment encompassing different ride factors.

Strandemar's study offers that methods of objective evaluation need to be related to the driver perception of their experience within a vehicle. This approach is somewhat counterintuitive, in establishing objective reasoning from subjective responses. However this means that the measures need to be more empirical and faithful. For example, the study highlights the lack of reliability in subjective rating evaluations, and the difficulty in marrying objective measures to driver subjective experience. This emphasises the need to use methodologies including live test drivers rather than trying to gauge levels of comfort from computer simulations.

2.3 – Driver Safety

Research on driver behaviour and experience most commonly, and importantly, addresses driver safety. This is classified as behaviour and experience because, often, safety is a matter of attitude and perceptions.

Driving safety is the centre of abundant research because of the wide effects it has on society, namely the risk to both drivers and pedestrians as it can lead to risk of injury or death. Increased safety is always considered an important criteria, which can help sway customer decisions. Alongside the exponential increase in people purchasing and driving vehicles, safety becomes even more important. Although there are many different contexts in which safety may be explored, such as drink-driving, this research focuses on driver safety in terms of normal driving experience where safety is related to the controlled environment of a sober driver. Areas that are of interest to this study include driving style, speed and attitude, as well as memory-based decisions, emotions and attention as variables.

Alongside Da Silva's conclusions that the best approach to evaluate driver experience is establishing the negative experiences first, risks are known to be affected by poor design. Sarah Copsey's (2011) paper on Managing Risks to Drivers in Road Transport makes reference to the 'minimum health and safety requirements for the exposure of workers to the risks arising from vibration' (Griffin, 2004).

In other research such as Klaus Genuit's (2009) paper on Vehicle Interior Noise- Combination of Sound, Vibration and Interactivity offer an alternative perspective. Driver safety is strongly related to situation awareness and so it is vital to consider the relationship between safety and vibrations as a credible variable in establishing awareness. Genuit offers that vibration and sound do not need to be completely eliminated, both in terms of safety and eliciting a pleasurable driving experience. Vibrations in a vehicle demand an interesting balance because on one hand they contribute to long-term health risks, and potentially unattractive as ride quality, but they are also important in the type of ride experienced where it can contribute to a more pleasurable ride.

Despite the long term health concerns with vibrations evidence is derived from past studies suggesting vibrations can help to focus task prioritisation. Gugerty et al., (2004) suggests that allocating attention to more important tasks is at risk when there is a distraction, so that multitasking can be prioritised if steering wheel vibrations links the sensory experience to the cognitive. In other words, feeling the road through the steering wheel vibrations can help to focus driver attention, as well as increasing the consciousness of the driving experience. External driving stimuli may be less likely to hold the attention of the driver, putting their safety at risk, if the steering wheel offers the most prominent physical, exogenous, experience. This, in turn, encourages the driver to be 'ready' to react.

2.4 – Driver Behaviour

The driving experience is a combination of many events, ranging from those caused by the driver, other drivers, or external situations, and each is likely to elicit strong emotions. The risks are predicated on negative emotions, specifically anger and frustration when a journey does not unfold as anticipated or intended. The risk enters when those emotions affect the driver's attention or decision-making. Literature has attempted to define the overall model of the driver behaviour to best understand human responses in relation to many contributing factors. For example Parkes and Franzen looked at the dynamic model of driver behaviour (Figure 2.3) in relation to the knowledge of information that the driver needs in a vehicle.

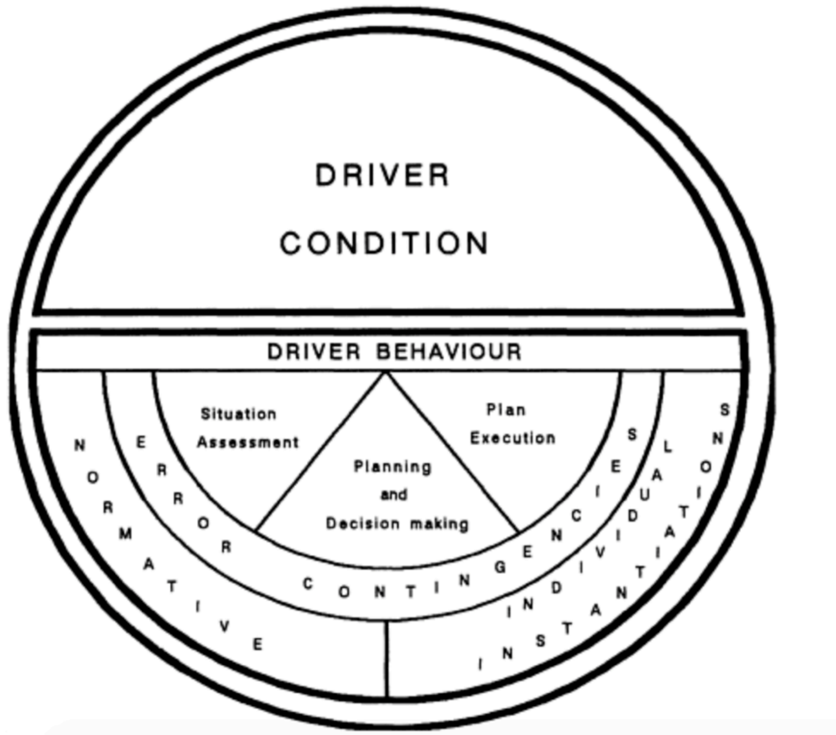


Figure 2.3 *Knowledge-based dynamic model fo human driver (Parkes and Franzen, 1993).*

While much research has been conducted on the effect of emotions on driver ability, the conclusions are usually drawn from research with a different focus, as emotion is not a readily quantifiable variable when addressing incidents or driving experience. It is only in cases where ‘road rage’ is suggested as the motivation for a particularly violent incident that emotion is considered as a factor warranting empirical research. As explored in exogenous and endogenous emotions, the function of emotions varies greatly depending on the environment or stimulus. For example, an unexpected manoeuvre by another automobile can elicit the emotion of fear in a driver, as an exogenous emotion this is likely to manifest as immediate reaction, or braking. Emotion is also used in order to communicate with other people, but this is difficult to do between two drivers in their own cars. This causes people to use their tools at hand, namely a horn or hand gesture, opening the line of communication to misinterpretation and aggravating situations that demand communications. Further, emotion is used to establish a strategy. Emotions can be used to plan a course in reaction, for example if a driver is in a position where they are blocking another driver but are trying to get out of the situation they might use a hand gesture to communicate apology, in other words a plan to appease a potentially negative interaction.

Models concerning driver behaviour, influenced by their emotion, first address the relationship between a situation and the task at hand for a driver, where emotions are elicited. Secondly they address the different types of emotional states that might have an effect on driver experience. There is scarce existing research that broaches a model to encompass these factors but there is abundant information available on related theories and concepts. Among these the Risk Models, namely the Threat Avoidance Theory, Risk Homeostasis Theory and Zero Risk theory are the most pertinent.

Threat Avoidance Theory (Fuller, 1984) considers drivers to be actively avoiding negative stimuli or threats. This means that a driver will actively avoid situations where they may feel has a risk of threat or where they feel they are in a position of threat, influenced by the physical environment, signs, or situations with other drivers. Risk Homeostasis Theory (Wilde, 1982), equally, suggests that drivers aim to attain a balance of target risk, or risk they are prepared to take and perceived risk. This theory suggests that where a driver has an aim (arriving somewhere at a designated time) they are willing to compromise on the perceived risks (speeding). Zero Risk Theory (Summala, 1997) offers that drivers use emotion as additional purpose. That is to say that depending on the progress and experience during a drive emotions may influence the rest of the experience, or emotions adjust the required response. An emotional framework for the driver may be derived as a combination of these three theories, dependent on the situation at hand and subject to appraisal theory which considers the emotion elicited in a particular situation or individual character. It also, however, highlights the tendency for theories to base a framework on negative emotions, whereas emotions theory proves that positive emotions can improve driver experience alongside theories that focus on negative emotions worsening driver experience. The potential of steering wheel vibrations and the positive impacts the correct balance it can have merit a framework that includes positive emotions or positive stimuli. Although the Appraisal Theory is based on 'transactional models of stress' (Mesken, 2006) it is valuable to use as a foundation and expand it to include impacts of positive emotion.

Chapter 3 – Research methods for measuring emotional response

3.1 – Introduction

Throughout history, understanding emotions and the application of that knowledge has been a strong focus (Cohan and Allen, 2007; Evans, 2001), the application of which ranging from the most basic to the most complex. Understanding the effect of emotion in relation to perception, preference and experience has become increasingly of interest in the modern age where companies no longer sell items, they sell narratives. In an age where product manufacturing, especially, has become saturated in design and delivery, an ability to tap into emotion is key to capturing attention. Similarly, from a design perspective, perception and experience are important points of information in considering emotional responses. Automotive design has traditionally looked at the emotional response of drivers in terms of negative emotions elicited by the technical elements of design, for example excessive vibrations created by the automobile mechanics.

Developing an understanding of human emotions elicited by mechanics begs the question of which emotions count, beyond the positive and negative, the utilitarian and the hedonistic. Basic emotions are found in all cultures and are reflected with the same facial expression in all cultures, including joy, anger, distress, fear, surprise and disgust. Although basic emotions are hard wired and the same for all humans this is not the same for culturally specific emotions, which tend to be confined within small culture groups, Evans (2001). The intersection between emotions and experience highlights key drivers to being able to reach the consumer. Understanding the basic and higher emotions of the consumer, and looking at the impact of experience as a driver, presents an opportunity in being able to manipulate key variables in those experiences to elicit a desired response.

This chapter considers the existing literature surrounding emotions as innate characteristics of product experience, including the research methods of customer satisfaction and jury evaluations used to measure the user experience.

Russell (1980) established the theory of Core Affect, which he describes as "A neurophysiological state that is consciously accessible as the simplest raw, non-reflective feelings evident in moods and emotions" Russell (2003). Russell in basic believed that because differentiating emotions vary greatly but at the same time have close interrelationships, they could be organised in a simple bipolar model where every basic emotion could be categorised within. This model called the Circumplex Model of Affect consists of two of the main dimensions that can be used to pinpoint a specific emotion. A schematic of the original model is featured on figure 3.1, which includes 28 various affect terms.

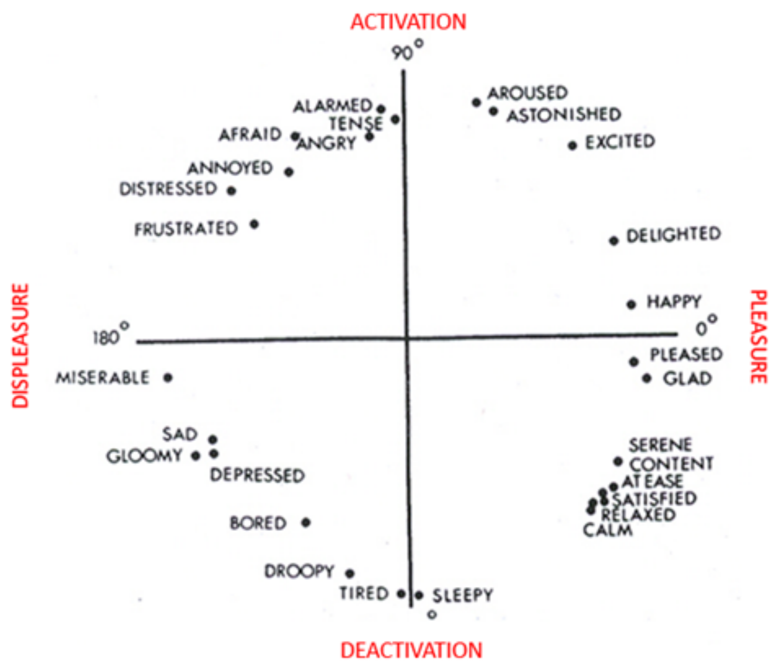


Figure 3.1 *Russell's Circumplex of affect.*

More recently the model has been redeveloped by Yik et al., (2011) shown in figure 3.2, which features 12 more specific dimensions which can be used to place any emotion more accurately within the main bipolar model of activation of pleasure and activation.

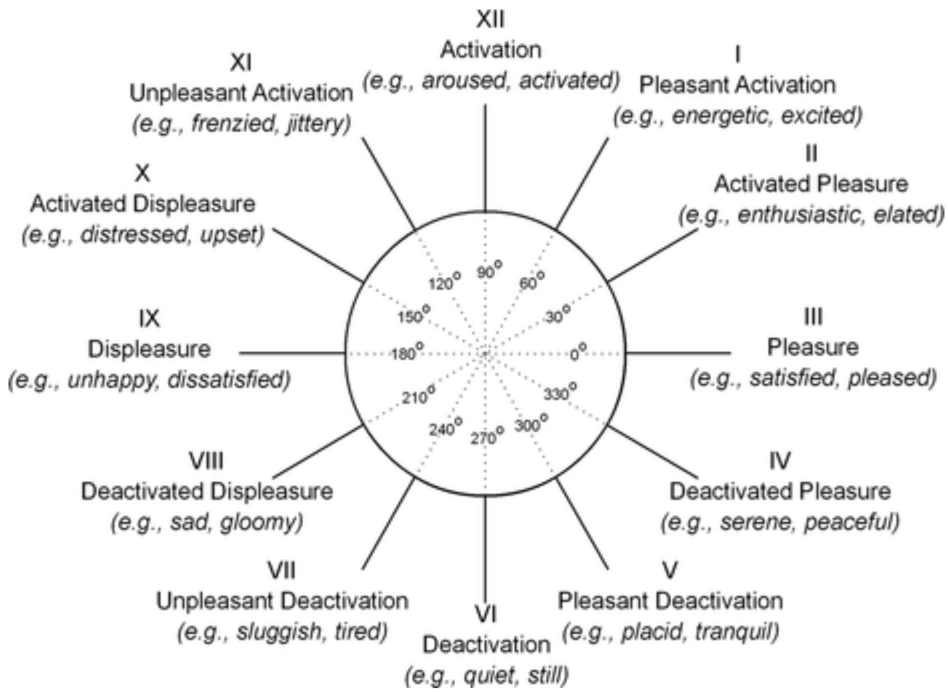


Figure 3.2 *Circumplex of affect.*

The use of the main two dimensions of pleasure and arousal has been consistent in many studies to quantify and evaluate emotional experience, various research (Kubo et al., 2009; Demset, 2003; Russell, 2003) carried out have used pleasure and arousal to map out emotional response of various experimental results.

Demset (2007) attempted to facilitate designers with the design of more emotionally stimulating products by evaluated the framework of product emotional experience where he concluded that it is possible to differentiate trends and patterns of emotional perception, the affective stimuli experienced and the cognitive processes (concern) that underline these experiences, play an important factor of the overall emotional state. These two factors are only vital to the individual if the encountered perceptions are appraised as having a significant importance to their personal well-being or safety. A schematic of the basic model of product emotions is displayed in figure 3.3.

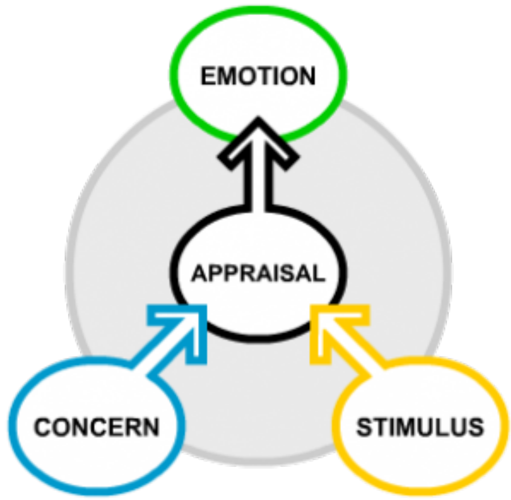


Figure 3.3 *Basic Model of Product Experience (Demset, 2007).*

3.2 – Approaches on the Theory of Emotion

In its most basic form, emotion is considered to either be positive or negative. To some extent the same can be said with regard to products and how we feel about them. Products make us feel a certain way, even if that feeling is as basic as satisfying a need for hunger or shelter as depicted in Abraham Maslow's Hierarchy of Needs (Figure 3.4)

Figure 3.4 *Maslow's Hierarchy of Needs (1943).*

Although Maslow's depiction of needs in order of importance or urgency has been decried as being too basic and lacking appreciation for the sophistication of modern emotions, it offers enough insight into a the variety of priorities. Depending on the product, and the emotions elicited by it through design and marketing, a product can inspire the full range of needs.

Griffiths (1997) suggested that there are three groups of emotion, basic emotions, cultural emotions and higher cognitive emotions. This is in keeping with Maslow's hierarchy and reflects the needs in priority from most urgent to learned ones, highlighting that the latter can be influenced more readily due to the wider variety of conditions. Basic emotions are more innate than higher cognitive emotions and culturally specific emotions, because they require less special conditions for that emotion to be perceived. Whereas for a higher cognitive emotion like love requires a more specific conditions like the other persons affection. Higher cognitive emotions are less innate than basic emotions at the same time more innate than cultural emotions. This is evident in figure 3.5, which shows a schematic adapted from Griffiths (1997) theories on emotion, it includes the three different types of emotion groups and their differentiating characteristics.

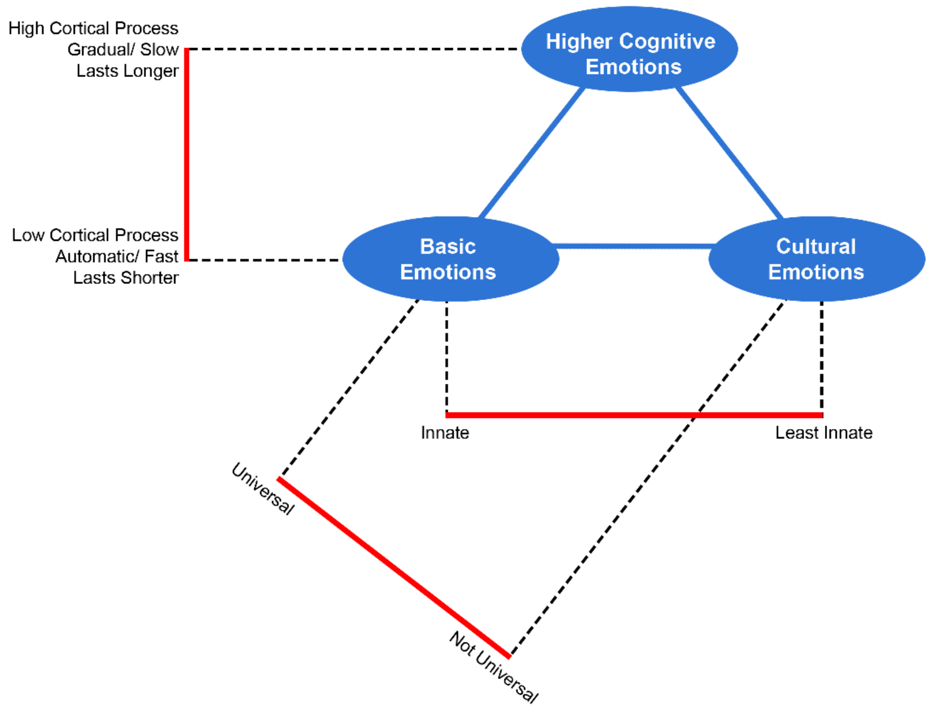


Figure 3.5 *Types of Emotions and their Characteristics*

The driving environment is a complex cognitive situation where the behavioural and emotional response can be detrimental to the driver's safety, wellbeing and experience. The automotive industry needs to pay great attention to the information and meanings they portray to the driver as slight misinterpretations could lead to negative experiences. Traditionally for automobiles the emotional response to vibrations has been considered in terms of annoyance and discomfort and mainly the need for high intensity level reduction has been addressed (Nahvi, Fouladi and Nor, 2009; Dempsey, Leatherwood and Clevenson, 1976; Dempsey, Leatherwood, and Drezek, 1976; Han et al., 2006).

Schifferstein and Hekkert (2008) defined product experience as the users awareness of the psychological effects elicited by interactions with the product, the intensity that our senses are simulated, the meanings we attach to the sensor data and the feeling and emotions elicited. This same definition is applicable to the driving experience as it too is the drivers' awareness of the psychological effects elicited by in vehicle interactions. Similarly the framework of product experience (Desmet and Hekkert, 2007), which distinguishes the three main components of user-product experience include aspects such as aesthetic pleasure, attribution of meaning, and emotional response. The experience of a driver while interacting with a vehicle can be shaped by a wide variety of emotions, vice versa our emotions can be shaped by experiences, which suggests the need for understanding and conditioning of the driving behaviour.

Recent trends in understanding deep levels of emotional interaction and users perceptual responses have developed different approaches towards design innovation all centred on the users interpretation of product or environment. Desmet (2002) presented the basic model of product emotions which describes three variables contributing to the emotional response, as being the stimuli of the object, the appraisal of the object and the concern regarding the object. An additional approach proposed by Norman (2004) is the process level approach to product affect which are involved in affective product experience, the three levels include the visceral, the behavioural, and the reflective levels which can all be engaged using enhanced user emotional experiences. Alternatively Jordan's (2000) pleasure based approach classifies four theoretical types of pleasure: physical pleasure, social pleasure, psychological pleasure and ideological pleasure that users may seek.

Norman (2005) suggests that even the most vital intelligent devices could become a source of annoyance is the relationship between the user of the device is not constitute a perfect match. By this notion it is evident that it is not sufficient to simply understanding what basic emotional reactions are elicited by the vibration stimuli but to understand the vocabulary used to describe the feedback elicited and what they mean to the driver, in return building an understanding of the communication language of steering wheel vibration characteristics. An automobile that responds and matches the driver's personality or behaviour will allow for a closer relationship to build for an enhanced driver vehicle interaction.

Emotions can be viewed as inhibiting intelligent action. This is true to some extent, where emotions manifesting in action can either be carefully thought out and influenced by intuition, or illogical and counterproductive, such as road rage. Anger, for example, can lead to an assault which can lead to an individual regretting their actions. Anger would be a counterproductive emotion if it is not controlled by the individual, so road rage would mean that a driving experience is under the influence of a heightened negative emotional state and a likeliness of regrettable actions (Evans, 2001).

More recently, P.M.A Desmet's article Three Levels of Product Emotion (2010) draws on very similar categorisations of emotions, namely **usefulness, pleasantness and rightfulness**. Desmet's appreciation of emotions is more suited to product development as it links corresponding emotions to experiences or, more specifically, how people evaluate their senses in relation to products. The intrinsic layers of emotion in Desmet's article are developed to include the product as the emotional stimuli. In trying to relate their innate feelings, Desmet suggests that the modern consumer tries to understand their relationship with a product as being either related to the qualities of the product, or the uses of the product and the personal outcome of using it. Each of these three frameworks resonates with a range between utilitarianism and hedonism, a concept widely echoed in consumer theory (Ahtola, 1985; Drakopoulos, 1992; Foxall et al., 1998; Adomaviciute, 2013). The range of literature available reflecting the dichotomy shows a trend towards the more hedonistic motivations and how this affects consumer behaviour. From the base emotions to the higher, and more complex, to the variable of secondary stimulus evaluation, as outlined by Desmet's second proposition, consumer emotions have to be considered contextually as well as temporally.

Dan Hill's Emotionomics (2007) explores more deeply emotions in context, or the way they react in conjunction with particular circumstances. The focus is on contextualizing emotions with a modern definition, secondary emotions as other than the primary or core emotions, and the way emotions relate to different actions. Hill also considers motivations as crucial to the experience of emotion, although emotion can be elicited from unintended or unplanned experiences, in consumer theory motivation helps to contextualise the types of emotional reaction to a planned circumstance and the reasoning behind it. Finally Hill considers the Emotionomics Matrix, a model used to widen strategic planning in product development; the matrix considers a more comprehensive range of emotions, 'not only rational elements but also the often neglected human factors of emotions and motivations.' (p76).

An interesting alternative view offered by Hill offers that emotion is separate to rationality, that is to say that emotions are related to action whereas rationality is related to thought and consideration. While the argument is valid to a degree as most definitions of emotion agree it has characteristics of **feeling, intuition and action**, it is not in keeping with more comprehensive interpretations of emotion in relation to products. When considering emotion in relation to automotive as 'products' there is overwhelming amounts of literature reinforcing the element of logical thought. An individual experiencing a drive uses their emotions to evaluate the experience. If they identify fear or apprehension from a very bumpy or jagged drive they are able to connect this to the logically established risk involved. Likewise, an experience that is pleasurable can be derived from 'feeling' the control of an automobile, the vibrations on the steering wheel alternate depending on the manoeuvre being made, the speed, positioning and terrain, making the individual feel confident and positive.

3.3 – Theory on Cognitive Processes of Emotion

3.3.1 – Memory Based Attention

Being able to choose information to process, or pay attention, using information you are able to access (memory) are important parts of cognitive ability. There has been extensive research in looking at attention and memory but less has been done to consider how the two are linked to emotion. Even though respectively neither is specifically seen to show regulated processes past research mostly looks at select aspects of each.

Duncan et al., (1997) suggest the hypothesis that a single cognitive mechanism controls both memory and attention, accepting that although there may be separate processes for each there is a single convergence. Arguments like this have been disputed because they don't really take into account the way verbal memory and visual attention function (Woodman et al., 2001). A more confident theorist is Cowan (1995) who argues that memory and attention are subject to the limited capacity for attention and the effect of long-term on short term memory. This is pertinent to researching human emotional response to automotive steering wheel vibrations because it refocuses the attention and memory dynamic to the present. Contextualising the driving experience means redressing the balance of different states of memory. In relation to Griffith's schematics of emotion the long term memory is related to higher cognitive emotions, or those more hedonistic, combined with the short term memory that relates to base emotions. In terms of emotional response to steering wheel vibrations this maps out the different types of emotions, and the way memory affects which is experienced. The long-term memory based attention can be said to relate to deeper, more subconscious desires, whereas the short-term memory based attention may be related to immediate needs and reactions. The immediacy of sensory perception through vibrations may elicit a particular type of emotion in the driver, unbalancing the short and long-term memory based attention in favour of the short. The work conducted in this thesis has therefore started to analyse the effect of long-term memory experience on the driver's emotional response to steering wheel vibration.

3.3.2 – Attention, Decision-Making and Emotion

Attention is most readily roused when emotions are stimulated. People are largely introspective in that they consider their environment in relation to themselves and how they feel in the moment, leaving the 'other' environment as secondary stimulus. Past research suggests that, further than having a reciprocal relationship between emotion and attention, emotion will also have a strong impact on memory. Excitement is likely to resonate with feelings of motivation, and so helps people to remember a piece of information with that attitude. Further than just remembering it, however, emotion affects the way we understand information. This goes some way to highlighting the challenges of influencing experience. In automotive design it is a sensitive business to create specifications that elicit a chosen type of response or a positive emotion as it is difficult to anticipate what environments people could feel negatively about due to past experience.

The balance between people's capacity for sensing information and the amount of information present in our environment means that it is important to consider the amount and type of information we take in. Between reading information from our senses and retaining it we also assess the value of that information, either consciously or subconsciously. The impact of emotion on attention is closely related to prioritisation, and how that leads to choosing information to retain focus on. In other words, depending on how much emotion is linked to a focus, dictates the length and intensity of our attention.

Researchers such as Ohman (2005) offer that behaviour, and attention specifically, is highly dependent on the motivations for affording that attention. There needs to be an emotional goal for giving something attention; this relationship is physically proven through evidence of the subcortical neural structures dictating the way attention is given to something, moderated by emotion (Zikopoulos and Barbas, 2012). Further, research on behaviour argues that the relationship between processing emotions and how much attention is afforded results in further emotional stimulation and reacting accordingly. If that relationship and the outcome is desirable to what the person wants to feel then attention is given in order to perpetuate that emotion (Zikopoulos and Barbas, 2012).

3.3.3 – Situation Awareness

Situation awareness (SA) is commonly defined as the knowledge of what is happening around you, for the ability to understand how information, events and your individual actions will impact goals and objectives in the future or immediately.

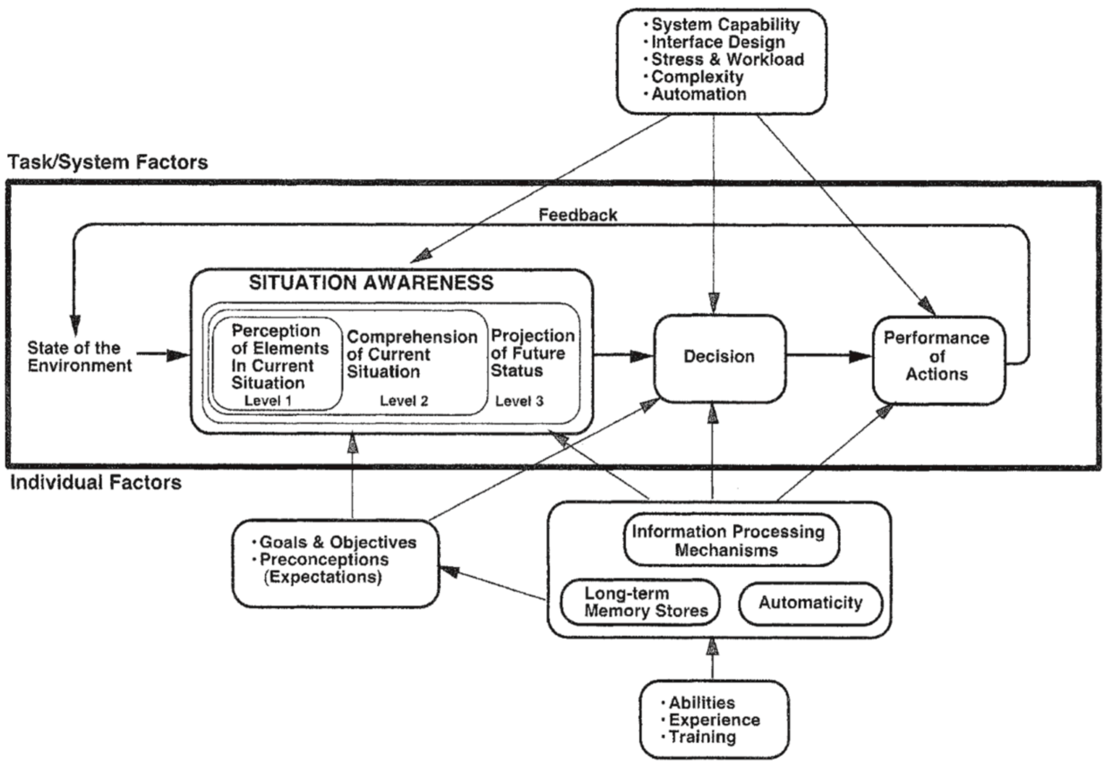


Figure 3.6 *Model of situation awareness in dynamic decision making (from Endsley and Jones, 2012)*

Understanding the role of emotion on both decision-making and attention is pivotal to understanding the driver experience because driving is very demanding of both the latter. In considering the driver experience in terms of decision-making and attention research has addressed the cognition and perception involved in a person being able to maintain the necessary awareness in driving. Specifically research has explored how it is possible to gauge this awareness as well as developing particular models to understand what the process of awareness involves and how essential it is for driving. The importance of feedback is highlighted in the basic model of situation awareness (Figure 3.6), as it can greatly affect the levels of awareness (Endsley et al., 2012). Simply put, awareness processes combine perception of feedback, the attention afforded to it, and the ability to effectively react in decision-making depending on the situation. Lee et al., (2004) have further explored the definition of SA, offering that the process involves 'focal vision and attention, including attention allocation, event comprehension, and task-management

3.4 – Measuring Emotions

The review of the literature shows that various factors contribute to the components that characterise the perceptual processes of automotive or product preference. It is also clear that emotional reactions play a key role in product user interaction and to influence purchasing behaviour. A famous quote by Lord Kelvin states that 'If you can not measure it, you can not improve it', and it is evident that efforts to measure emotion can be traced as far back as Darwin. The next step was in being able to understand emotion in people, or being able to measure it without being told by the person experiencing an emotion. Appraisal theories that developed after this took into account both the conscious and subconscious physical manifestations of emotion on a human, and even further were considered according to how they were affected by their cultural values and other impacts, and now has rapidly grown into its own scientific branch namely affective science.

Researchers such as Ekman and Scherer (1984) took cross-cultural evaluations of emotion and suggested that it offered an evolutionary advantage in communication. Important aspects derived from their studies distinguished and linked relationships between emotion, mood and behaviour, and the consequent actions motivated by the former. More contemporary studies such as Davidson and Cacioppo (1992) have argued that emotion is important to different response types and are an extension of psychobiological, collective and behavioural variables as well as information processing.

Research into the relationship between emotion and sensory stimuli is a movement that has slowly but surely gained a lot of interest, expedited by the consumerist behaviour of the 21st century automobile. Economic security, credit and bigger disposable incomes have resulted in an increasingly hedonistic society, which has inspired research into why we feel the way we feel about the things we buy. Saturated markets are interested in understanding emotional connections and motivations because it helps them attain a commercial advantage between the audience and the brand. Desmet (2002), among others, has taken this concept and explored more fully the way that understanding emotion can help support product designers to understand what emotional effect their products have on the consumer. Of the wide range of literature now available on emotions theory and research, it is vital that the focus in this study remains on understanding the measuring criteria of the semantic space (vibratory language) of the steering wheel feedback felt by the driver.

3.4.1 – Types of Measures

Techniques used to measure emotions are typically characterised into physiological measures and subjective measures. With the development of new sensors and technologies, physiological measuring techniques have expanded greatly to capture a range of physiological bodily processes. Physiological measures are carried out using various equipment, such as fMRI, EEG and galvanic skin response (GSR), muscle tension and hormone monitoring. More recently facial imaging software, facial action coding systems and emotion analytics systems are being used to capture real time user experiences without interacting with the user as they perform tasks. The main advantage of physiological measuring techniques is that they primarily measure the body’s responses to stimulus, as oppose to the subjective measuring techniques that are mainly based on the persons interpretations of the cognitive processes of the felt stimulus which have been seen as biased due to their subjective nature. The main disadvantage of physiological measuring techniques is that often at times it can be difficult to translate the results into a wide range of emotional responses and instead the results will be limited to certain bodily response characteristic such as skin conductance, heart rate, temperature, electroencephalography and other non-intrusive measuring apparatus. Instead subjective measures give researchers the ability to measure a greater aspect of emotional characteristics and to gather direct and meaningful responses. There has been an even wider adaptation of subjective measuring techniques by researchers, especially for self-report (questionnaire) based research, which have allowed a great numbers of data to be gathered from all over the word which is almost impossible to reach using physiological techniques. As this study is looking at the driver's emotional response to the perceived steering wheel vibrations, subjective measuring techniques are the best choice to evaluate the meanings and emotions we associate to the perceived stimuli in order to understanding the measuring criteria of the semantic space steering wheel vibration feedback.

3.4.2 – Subjective Measures of Emotions

In rating-scale tasks research subjects are asked to put a numeric value on their reaction to a stimulus using Likert type scales. In this case, this exercise can be used to look at the way each stimulus compares to the others as well as measuring an emotional response on a scale of intensity. Rated response tasks are designed to indicate how stimuli vary in the estimation of the individual according to a set dimension or range. To which typically the response will be measured on a scale from 1 (Very pleasant), 2 (Pleasant), 3 (Neutral), 4 (Unpleasant) to 5 (Very unpleasant). Research also concurs that questionnaire questions should: avoid jargon, slang and abbreviation, and to avoid ambiguity, confusion and vagueness. In this research, where eliciting an untainted emotional response is pivotal to empirical data these rules are critical. The questions need to be clear but they must also not be leading or giving hints. Various rating scale techniques have been used to examine subjective emotional experiences, many models and tools have been developed to capture different dimensions and categories of emotions. Desmet

(2003) developed the Product Emotion Measurement – PrEmo (Figure 3.7.A) instrument which includes 14 various emotional options to choose from, each emotion is accompanied by a animated character which includes emotional facial, bodily and vocal characteristics. Each of the emotions was selected to cover a cross section of the variety of possible feelings elicited by product experience. The Semantic Differential Scale (Figure 3.7.B) developed by Osgood et al., (1957) can be used with any experiment related emotional descriptor in order to get the desired results. The actual scale runs from -3 to 3 with zero being neutral. Results show a clear chart with trends for easier assessment. A growing number of researchers use the Self-assessment Manikin (Lang, 1980) shown in figure 3.7.C as it provides a self-explanatory method of quantifying the emotional experience felt with clear graphics displayed in three dimensions of Pleasure, Arousal and Dominance. It measures all necessary dimensions to exactly quantify an emotion. The Affect Grid1 (Figure 3.7.D) by Russell (1989) is another affective method of measurement as it is structured around the previous developed Core Affect and required the participant to directly map out their emotion on the two dimensional chart.

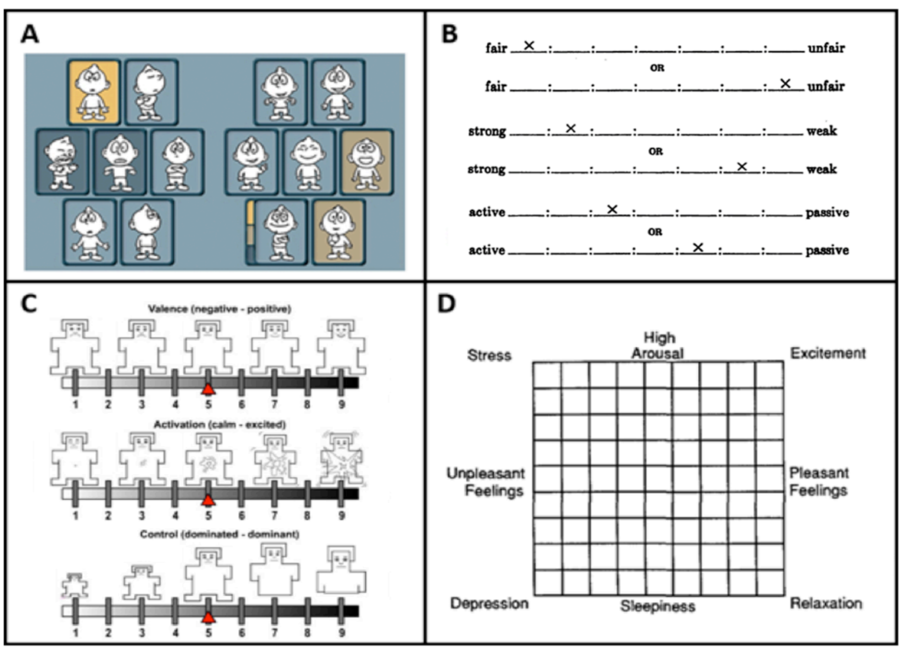


Figure 3.7 A:*PrEmo model (Demset, 2003),* ***B:****Semantic Differential scale (Osgood et al., 1957),* ***C:*** *SAM, (Lang, 1980)* ***D:****Affect Grid, (Russell, 1989).*

When comparing all of the above emotional measuring techniques it is vital to choose a model that will address the research goal of evaluating the emotional experience. The PrEmo method does cover the pleasure and arousal dimension well but it could be more complicated than other models to use by participant. Bradley and Lang (1994) compared the Self-Assessment Manikin against the Semantic Differential scale and concluded that when using the semantic differential scale for three affective dimensions there are not many differences in the results between pleasure and arousal whereas for the dominance dimension the results proved more conclusive for the SAM assessment model. Finally the Affect Grid does have its advantages of making the result gathering easier after the experiment but the only concern is whether the participant will find it easy to continuously and accurately write down their emotional experience within the bipolar model. Although all four measurement models are widely used in experimental research, the semantic differential technique is best suited for the aim of my study which is to identify the meanings drivers associate to the perceived stimuli rather than a pre set choice of descriptors. Although the semantic differential scale has been shown to translate to the basic three recurring dimensions of evaluation, potency, and activity, it is important to evaluate the exact language associated specifically to automotive steering wheel vibrations, as the assessed dimensions of attitudes should be context specific if we truly want to discover the real connotative meaning behind a concept. The only drawback in using Osgood's (1957) semantic differential technique is that compared to the other three it involves a more rigorous and lengthy method to capture the dimensions and build the context related scale. With this understanding, it is important to consider a preliminary study that can be used to first identify if there is an effect on the human emotional response to automotive steering wheel vibrations, before starting to focus the specific emotional response. This could in turn allow for a more efficient process of answering the research question and could prove more time efficient.

3.4.3 – Importance of Emotional Semantic Descriptors

Studies looking at specific emotional responses to various stimuli have also greatly increased in the last decade; this is especially the case for automotive research. The measurement of attitudes is becoming more crucial everyday to automotive manufacturers as the competition grows. By identifying the optimal semantic descriptors that can describe the felt driver experience during driving conditions it is then possible to address the desired experience so as to help customise the aspects of the automobile towards a specific brand quality or product characteristics. Table 3.1, presents a summary of existing research studies which look at the attributes that driver's use to describe perceived sound and vibration stimuli. The table includes the journal paper title, the type of research stimuli being tested and the semantic descriptors used to evaluate the stimuli in each study.

Table 3.1 *Sample of research studies and the significance of human subjective verbal descriptors*

Paper	*Types*	Attributes / Descriptors
The development of a multidimensional scale to evaluate motor vehicle dynamic qualities.	Ride handling and steering qualities of motor vehicel	Communicative/V ague, Informative/Uninformative, Accurate/Inaccurate, Precise/Imprecise, Responsive/Unresponsive, Sensitive/Insensitive, Interactive/Uninvolving, Well-weighted/Poorly-weighted, Quick/Slow, Speedy/Leisurely, Frisky/Sluggish, Good acceleration/Poor acceleration, Rapid/Slow, Exciting/Dull, Predictable/Unpredictable, Controlled/Uncontrolled, Stable/Unstable, Solid/Loose, Composed/Fidgety, Firm/Soft, Settled/Unsettled, Firm/Bouncy, Poised/Nervy, Oversteer/No oversteer, Body roll/No body roll, Taut/Slack, Understeer/No Understeer, Absorbent/Thumpy, Smooth/Harsh Comfortable/Uncomfortable, Grippy /Skiddy, Adhesive/Slippy, Light/Heavy
Multi-sensory congruence in vehicle sound quality assessment: Effects of vibration and irrelevant emotional primes on affective reactions and evaluations of product sounds.	Sound and vibration stimuli	Valance, activation, annoying, powerful, high quality, howling, suitable, rumbling
Investigation into Induction of a Feeling of Pleasure Caused by Vibration	Seating vibrations	Unsatisfied/ satisfied, restless/ self-possessed, hard/ pleasure, lifeless/ exhilaration, uneasy/ relieved, vague/ refreshing, displeasure/ pleasure, quiet/ awakening.
An Affective Engineering Study of Vibrational Cues and Affect When Touching Car Interiors	Touch of car interrior	Cheap, Quality, Masculine, Engineered, Warm, Exciting, Comfortable, Sophisticated, Relaxed, Unique, Sporty
Describing product experience in different languages: The role of sensory modalities	descriptive atributes relating to touch	Pleasant/ unpleasant, agreeable/ disagreeable, good/ bad, attractive/ unattractive, seductive/ repulsive, inviting/ rejecting, active/ relaxed, stimulating/ relaxing, excited/ calm, tense/ fusty, lively/ quiet, gentle/ tough, masculine/ feminine, strong/ weak, rough/ soft, interesting/ boring, safe/ dangerous, expensive/ cheap, valuable/ worthless, predictable/ unpredictable.
Vibro-acoustical comfort in cars at idle: human perception of simulated sounds and vibrations from 3- and 4-cylinder diesel engines	Sound and vibration stimuli	High level, shaking, damped, annoying, sharp, pleasant, windy, regular, front located.
Correlation between subjective and objective measurements of steering column shake to determine design specifications for the steering column structure	Steering column shake	Undetectable, must tune in, detected, aware, desirable, annoying, unacceptable, intolerable, painful, destructive,
The Ford Vehicle Vibration Simulator for Subjective Testing	Sound and vibration stimuli	Satisfactory/ unsatisfactory, smooth/ rough.
Vibration perception and excitatory direction for haptic devices	Perception of haptic devices	Light, Numbed, Sensitive, Interesting, Repulsive, Delightful, Ticklish, Soft, Exciting, Dizzy, Joyful, Scary, Drowsy, Offending, Thrilling, Fearful, Discomfort, Surprising, Straining, Anxious, Threatening, Satisfied, Painful, Enjoyable, Irritating, Likable, Stable, Pleased, Stinging.

Factors affecting the driver's emotional attitudes vary greatly since emotions are produced by every perceptual stimulus, so measuring the subjective descriptors or attitudes is important due to the ever changing contextual surroundings. Emotions in themselves are also very subjective as they vary greatly depending on the individual's personality characteristics. Also the cognitive processes used for emotional perception have many factors that can affect the overall response. And there are in turn many other sources that can affect the emotional response of a driver that can overpower the haptic stimulus perception.

3.4.4 – Semantic Differential Technique

The research studies based on assessments of user subjective descriptors presented in the literature (table 3.1), show that the experimenters carrying out the studies, most commonly are the ones whom choose the measuring criteria of emotions. This is either based on some preliminary feedback from participants or on set target benchmarks. Although subjective evaluations such as these are effective at measuring participants responses, one of the most commonly tool used to measure the attitudes behind a concept is the semantic differential technique, as it can be applied to a variety of applications. To quantify emotions, current research suggests that the Semantic Differential technique is the most efficient tool to build on the connotative meanings used to understand the attitudes associated with a chosen concept (Himmelfarb, 1993), which in this case is applicable to the automotive steering wheel vibration feedback. Literature shows that subjective evaluations and the criteria used to assess them need to be context related.

The development of the semantic differential techniques by Osgood et al., (1957), has made it possible for researchers to measure the attitudes and connotative meanings of the semantic language behind many chosen concepts. With the three typical recurring descriptors already defined to many concepts as evaluation, potency, and activity, the exact descriptors or adjective pairs relating to these dimensions need to be identified in the context of automotive vibration feedback.

Although a significant amount of research has been carried out to define the vocabulary or descriptors used in subjective evaluations and customer satisfaction techniques in context associated to the perception of automotive sound and tactile vibration, there is a no specific research that defines the emotional assessment criteria and the semantic descriptors associated to the experienced steering wheel vibration feedback in automobiles. The work presented in this thesis has employed a semantic differential technique so as to formulate and assess the reliability of a newly developed Driver Emotional Semantic scale to be used to evaluate the driver emotional response to steering wheel vibration in automobiles during driving conditions.

Chapter 4 – Measuring driver expectations and driver experiences

4.1 – Introduction

In order to understand how to measure the driver emotional response to automotive steering wheel vibration, the first step was to identify whether the vibration acceleration stimuli have an effect on the basic human emotional valence and arousal dimensions, before trying to identify the specific semantic descriptors for the vibration stimuli. This chapter introduces a comparison of two preliminary experimental test methods, the first is a questionnaire survey which investigates the correlation which may exist between the anticipated human emotional response to the steering wheel vibration as expected to be perceived from pictures presented showing the road surface types. The second study is a laboratory test bench experiment, which investigates what form of correlation may exist between measures of the human emotional response to steering wheel vibration. A comparison is carried out for the driver subjective emotional response of the valence and arousal dimensions from both tests, (the questionnaire survey and the laboratory study).

4.2 – Exp.1 – Picture based survey to measure the expected driver emotional response of automotive steering wheel vibration

4.2.1 – Questionnaire Survey Development

A self-administered questionnaire survey was developed in order to investigate whether a correlation exists between the anticipated measures of the valence and arousal dimensions of the human emotional response and the steering wheel vibration as expected to be perceived from pictures of road surface types. Among many advantages, the self-administered questionnaire was mainly used as it allowed for various dissemination approaches, which in turn makes it possible to collect a greater number of participant responses.

This study aimed to evaluate the human emotional response of memory-based perception of vibration expectations as elicited from pictures of road surface types. The pictures of the road test stimuli used for this questionnaire survey were seventeen steering wheel acceleration signals which were selected from an extensive database of road test measurements previously performed by the Perception Enhancement research group (Gnanasekaran, 2006, Berber et al., 2010). Figure 4.1 presents the seventeen road surface types assessed in this survey. To better assist participants with recalling their memory-based perceptions, both images, as viewed from directly above and as seen while driving, were shown for each road surface condition.

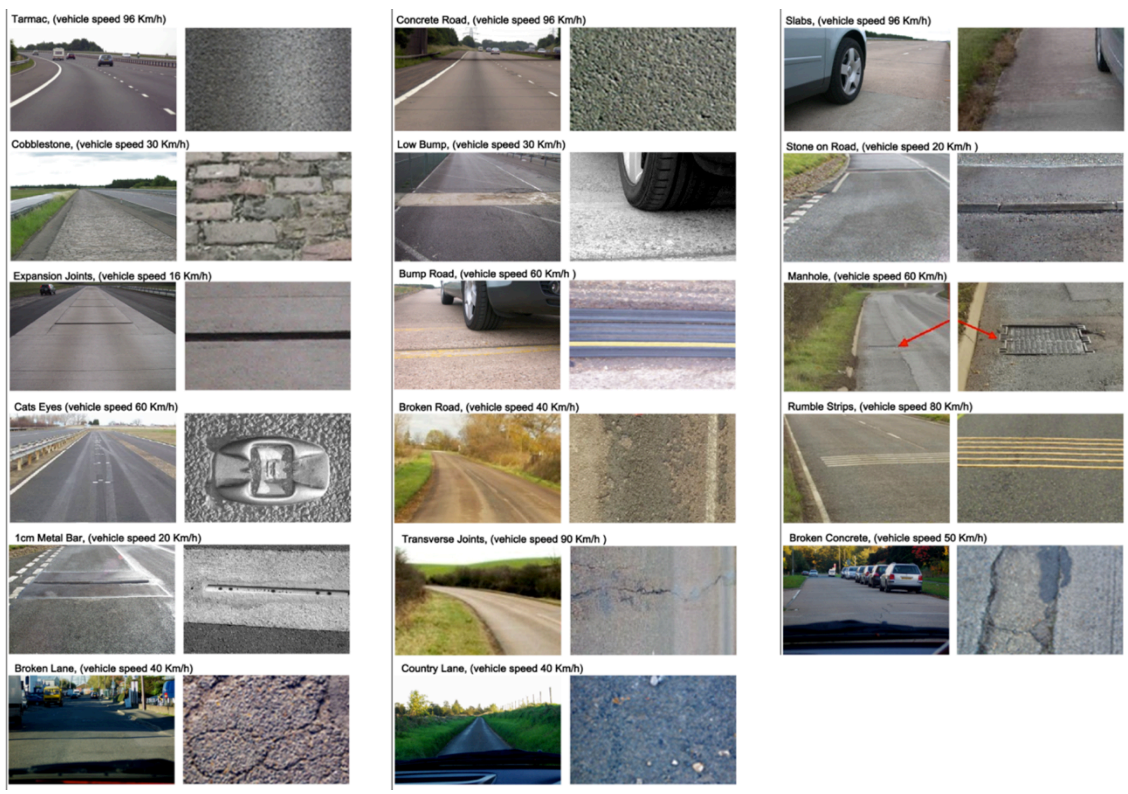


Figure 4.1 *Road surfaces and vehicle speeds whose stimuli were chosen for use in the questionnire survey.*

The names assigned to the individual road surfaces for organisational purposes were: 1cm metal bar, broken road, broken concrete, broken lane, bump, cats eyes, cobblestone, concrete road, country lane, expansion joints, low bump, manhole, rumble strips, slabs, stone on road, tarmac and transverse. Of the these, ten, namely 1cm metal bar, bump, cats eyes, expansion joints, low bump, manhole, rumble strips, slabs, stone on road and transverse joints can be classified as containing significant transient events, while the remaining seven, namely broken road, broken concrete, broken lane, cobblestone, concrete road, country lane and tarmac can be broadly classified as mildly non-stationary signals (Giacomin et al., 2000). A Transient event describes a short segment of an oscillatory wave, which greatly exceeds in magnitude when compared to the previous and future section's magnitude. Whereas a non-stationary or random event, can be defines as a signal with a constant signal magnitude throughout the overall length of the acceleration.

For purposes of simplicity, standardisation and facilitation of comparison with results from other fields (Greenwald et al., 1989), the emotional response of the test participants was measured by means of the well known Self-Assessment Manikin (SAM). Used in its most basic form (Cohan and Allen, 2007) the SAM consists of a set of symbolic graphical representations of the human body under various degrees of emotional response (see Figure 4.2). The graphical correlates of the emotional response are visually associated with a Likert format rating scale, which is used by the test participant to choose a numerical value to indicate his or her emotional valence (pleasure) and level of arousal (excitement). The Likert format rating scale provides values from 1 to 9 to span the range from unpleasant to pleasant to in the case of the valence, and to span the range from calm to excited in the case of the arousal dimension. In the basic form adopted for use in the current study the SAM provides a two dimensional measure of the human emotional state based on the direction and size of the response.

The use of the SAM scale has been found to be reliable and to be comparable to the human emotional responses derived from the relatively longer semantic differential scale (Bradley and Lang, 1994). The advantage of the SAM measure is that it can be understood by different ethnic populations, in different cultures and it is easy to administrate in a laboratory-based experiments as well as in questionnaire based surveys.

Instead of the standard slider of the 1-9 Likert scale, a check box was used under each value of the Likert scale to allow participants to clearly mark their response under both dimension of the scale (see figure 4.2). An example of how each of the seventeen road surface types was presented in the questionnaire is shown below in figure 4.2, which includes the two images of the road surface from different angles, the assigned name of the road and the vehicle speed, and finally the two dimensions of the self assessment manikin with the space provided for marking participants responses.

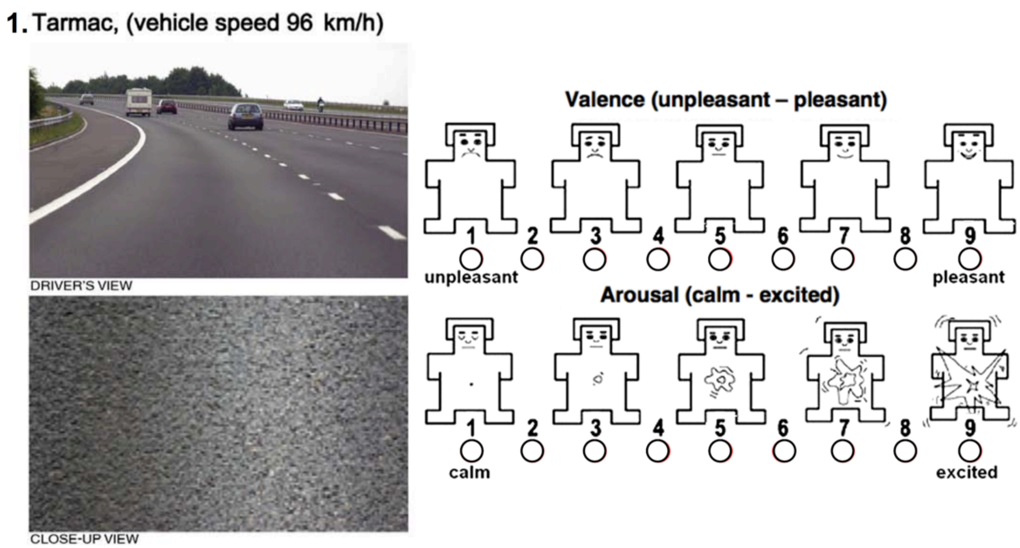


Figure 4.2 *Example of the questionnaire survey layout presented for each road surface type including the Self-Assessment Manikin (SAM) used to rate the affective dimensions of emotional valence (top panel) and emotional arousal (bottom panel). (Adapted from Bradley and Lang, 1994).*

A 10 page questionnaire survey was developed for this study, the first and the second page is presented in Appendix 1, which include two main sections A and B. Section A was used to gather personal data regarding the participants details, and section B was used to requests and measure the participants expected emotional rating of valence and arousal dimensions for each of the road surface types. Pages 3 to 10 were a continuation of the second page (Section B) showing the rest of the roads surface types, which were not included in the appendix.

4.2.2 – Questionnaire Survey Protocol and Dissemination

Full colour copies of the questionnaire survey were printed in paper-based form and disseminated out to participants. The same questionnaire format was also developed into an online interactive form, which made it possible to reach participants from all types of online sources such as automotive forums and message boards, emails and owners clubs. Online sources with a high rate of user traffic were used to disseminate the questionnaire. Although it is difficult to track the response rate without the actual website traffic statistics in order to know how many people visited the website and how many came across the questionnaire, the number of respondents however was as high as 100 participants from the online source. The questionnaire was also distributed to participants in public car parks along with a return addressed and pre-stamped envelope. A total of 150 responses were gathered for the questionnaire survey.

Before commencing the rating process for each of the road surface types, participants were instructed to: “Based on your driving experience please indicate the emotional ratings you associate with the steering wheel vibration of each of the driving situations listed below”, in order to clarity and find out whether they understand the main aim of the questionnaire. The average time required to compete the questionnaire was approximately 20 minutes.

Participant data was gathered, such as gender, age, weight, height, driving experience, automobile used and physical condition which may alter their perception of visual, sound or tactile stimuli. In order to maintain reliability of the responses, no data was analysed from participants who indicated a condition, which may alter their sensory perceptions. As the aim of the questionnaire was to measure the participant’s memory-based expected perceptions, participant responses that had less than two years driving experience were also not analysed in the final results.

4.2.3 – Questionnaire Survey Test Participants

A mock-up questionnaire survey was carried out with 10 participants in order to assess the suitability and readability of the questionnaire. The 10 participants were selected to be a representative of the general automotive driving population by having at least 3-5 years driving experience. Based on the participant feedback, the layout and the questions were adjusted in order to improve the participants understanding of the questionnaire aims and ease of use of the questionnaire structure. A total of 150 test participants took part in the final questionnaire survey, which included a mixture of university staff and students, family members and friends as well as other helpful online and community members. The group consisted of 112 male and 38 female participants. The participant age were selected to be a representative between the young and the senior general U.K. driving population covering a wide spectrum ranging from 19 years old to 65 years old. Regarding the difference between male and female participants, the majority of participants were male, which matches the figures of the general U.K. driving demographics (Department of Transport, 2010) although not to the same exact ratio (80% male / 66% female).

Table 4.1 *Physical characteristics of the group of test participants involved in the questionnaire survey (n=150)*

Characteristics		Mean	Standard Deviation	Minimum	Maximum
Age	**(years)**	30.2	9.3	19.0	65.0
Height	**(m)**	1.8	0.1	1.6	2.0
Mass	**(kg)**	80.8	12.9	55.0	115.0

Table 4.1 presents a summary of the physical characteristics of the group of questionnaire survey participants. The mean values and the standard deviation of the age, height and weight of the questionnaire survey participants were near the 50 percentile values for the U.K. driving

population (Pheasant and Haslegrave, 2005). The sample population was representative of the average UK driving population, which had a mean value of 11 years of past driving experience. Participant results that had less than two years of driving experience were removed.

4.2.4 – Questionnaire Survey Results

The questionnaire results for all 150 participants are shown in Appendix 2, which include every subjective rating of the valence and arousal scales for all seventeen road surface conditions tested. Table 5.2 presents the mean affective ratings and the standard deviation values obtained across the whole group of 150 participants for the valence and arousal responses to each of the seventeen road driving conditions analysed in this study.

Table 4.2 *The corresponding valence and arousal affective ratings and each of the road surface types assesed using the questionnaire survey (n=150 people).*

Road Surface Type	Pleasure rating mean (SD)	Arousal rating mean (SD)
Tarmac	8.19 (1.2)	2.02 (1.4)
Concrete	8.31 (1.1)	1.83 (1.4)
Slabs	6.37 (1.4)	3.05 (1.3)
Cobblestone	3.57 (1.5)	5.27 (2.0)
Low Bump	5.77 (1.7)	3.19 (1.6)
Stone on Road	5.49 (1.7)	3.75 (1.5)
Expansion Joints	5.29 (1.8)	3.88 (1.8)
Bump Road	5.01 (1.5)	4.29 (1.6)
Manhole	4.03 (1.5)	4.7 (1.9)
Cats Eyes	4.05 (1.4)	4.62 (1.6)
Broken Road	5.53 (1.8)	3.72 (1.7)
Rumble Strips	5.69 (1.5)	3.94 (1.8)
1cm Metal Bar	5.12 (1.8)	3.77 (1.6)
Transverse Joints	6.95 (1.6)	4.29 (1.6)
Broken Concrete	5.75 (1.7)	3.53 (1.3)
Broken Lane	6.06 (1.7)	2.97 (1.4)
Country Lane	6.45 (1.7)	3.29 (1.5)

As can be seen from table 4.2, the standard deviation was found to generally fall between 1.1 and 1.8, indicating equal difficulty on the part of the participant to distinguish memory based ratings for all of the road surface conditions tested. Additionally, it can be observed that the affective ratings obtained for the valence (pleasure) rating accounted for a larger dynamic range

(3.57-8.31(4.74)) of the nine-point SAM scale values as compared to the arousal dimension (1.83-5.27(3.44)). The mean values of result would suggest that the set of automotive road surface conditions are mostly expected to be perceived, as pleasant and calm sensations from memory-based estimations of the automotive steering wheel vibrations.

To investigate what form of relationship may exist between the valence and the arousal dimensions of the participants expected emotional response to the estimated steering wheel vibration, the questionnaire data were plotted in the two-dimensional affective space defined by the mean valence and arousal ratings for each road driving condition used in this study as shown in Figure 4.3. A regression line was fitted to the data of the valence and arousal ratings by means of least squares regression (Hinton, 1999).

The distribution of the data points in Figure 4.3 suggests that high levels of emotional arousal (excited feelings) of steering wheel vibration are mostly associated with low levels of emotional valence (unpleasant feelings), and that high levels of emotional valence (pleasant feelings) are associated with low levels of emotional arousal (calm feelings) of the vibration. With the exception of the transverse joints road condition, the rest of the participant valence and arousal expectation ratings are closely positioned along the regression line of the data point distributions.

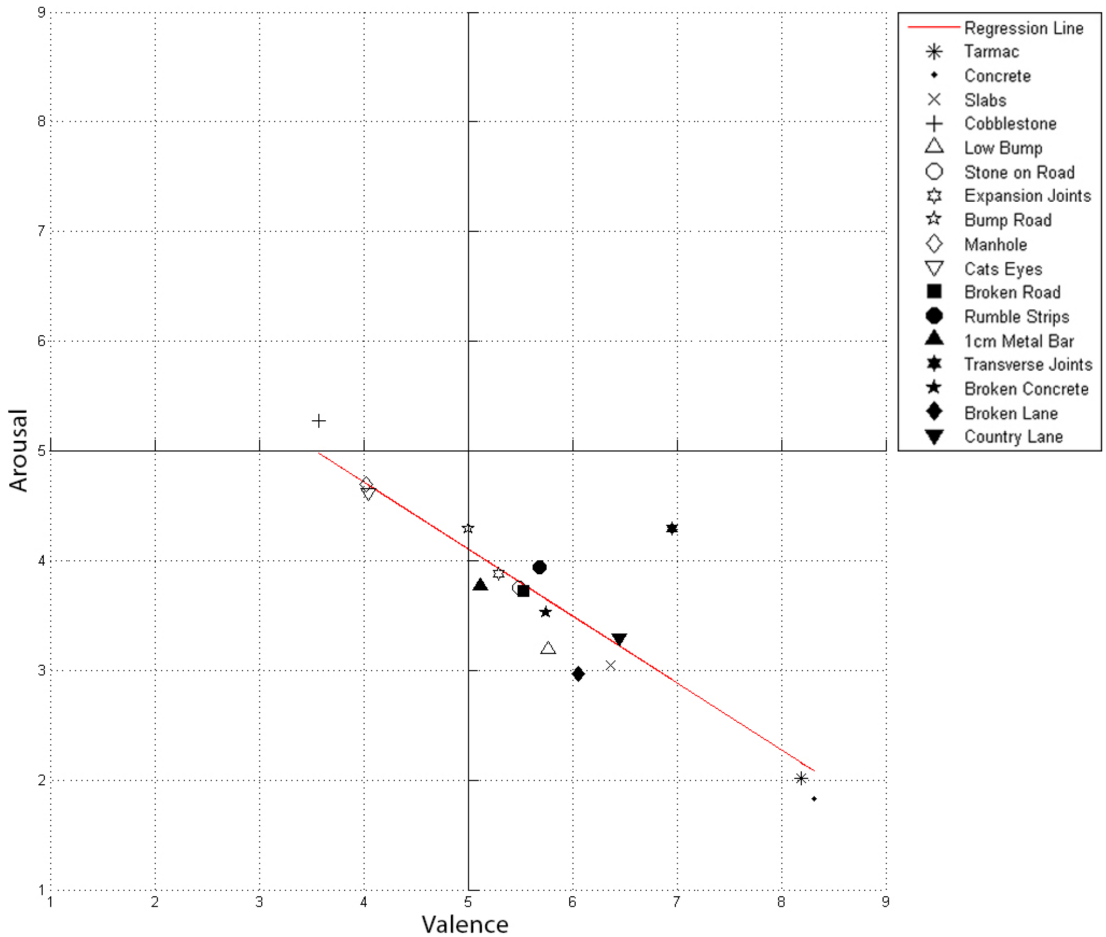


Figure 4.3 *The Two-dimensional affective space defined by the mean ratings of valence and arousal expected responses of automotive steering wheel vibration for the seventeen road driving conditions.*

Although the expected responses of valence and arousal show a linear correlation between the two SAM axis, some grouping can be seen within the responses. The road profiles expected to have medium intensity are shown to group around the mid waypoint of the regression line. The two common low intensity road profiles of Tarmac and Concrete road are grouped at the low arousal and high valence end of the regression line, with a wide gap between them and the medium intensity road profiles. The Cobblestone road was expected to be perceived at the most extreme of the regression line, as it can be understood that from just the various pictures presented to participants, it does appear as the roughest or most irregular out of the seventeen used judging on only the memory based expectation of automotive steering wheel vibrations from previous experiences.

4.2.5 – Discussion

This aim of this questionnaire study was to evaluate what form of correlation may exist between the measures of the valence and arousal dimensions of the human emotional response to steering wheel vibration feedback. The study measured the driver's emotional response as expected reaction to the vibration associated to the sight of a picture representing different road surface types as recalled from the driver's long-term memory experience.

The questionnaire results show that the greater the visual road profile irregularity is seen by the participants the higher they rate their expectations or estimations of activation and unpleasantness, suggesting that an increase in visual road profile irregularities will increase the driver's expectations of steering wheel vibration accelerations. From the comparison between the expected valence and the arousal dimensions (Figure 4.3) of the anticipated human emotional response, the results suggest that expectations of high levels of emotional arousal (excited feeling) of steering wheel vibration are mostly associated with expectations of low levels of emotional valence (unpleasant feelings), and that expectations of high levels of emotional valence (pleasant feelings) are associated with low levels of emotional arousal (calm feelings) of the expected vibration.

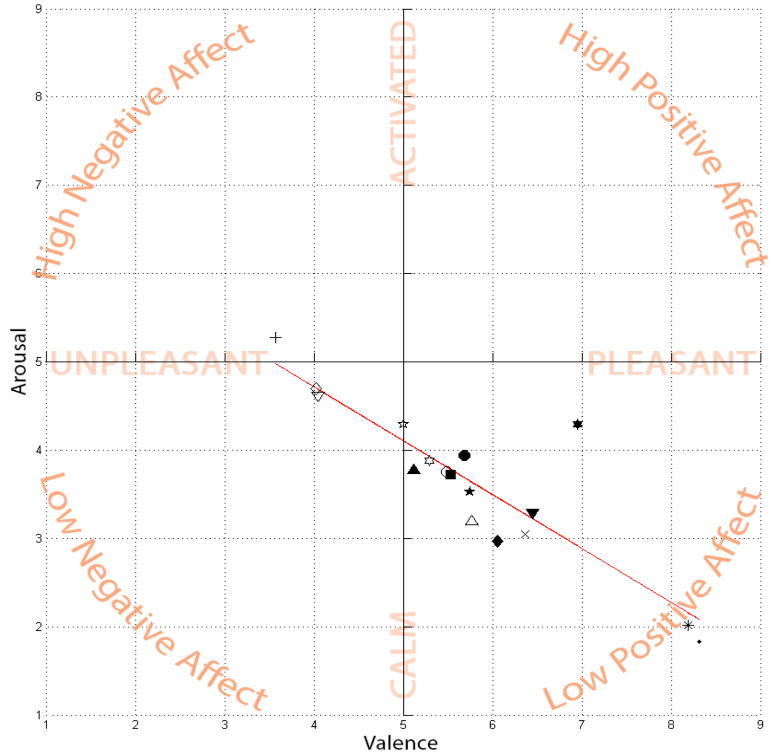


Figure 4.4 *Overlay of the two-dimensional affective space of the expected valence and arousal response over the circumplex model of affect.*

When looking at the expected data point distribution (Figure 4.3) and comparing it to Russell's, Circumplex Model of Affect (Figure 4.4), it is shown that the regression line falls between a low positive affect moving slightly towards a high negative affect, as the Cobblestone road profile ratings falls slightly past the scale value of 5 onto an activated emotional state. The variation in the expected human emotional response to steering wheel vibration for the valence and arousal affective dimensions is mainly dependent on the presence of road profile irregularity, with a heightened anticipated sense of the vibration intensity from the steering wheel acceleration stimuli. From the human emotional response of valence and arousal ratings based on the participant memory based expectations of steering wheel vibrations, it can be suggested that there are factors other than just the presence of the visual road profile irregularities which influence the expectations of human emotional response to steering wheel vibration, although this could be mainly due to the drivers past experiences of the automotive steering wheel vibration.

4.3 – Exp.2 – Laboratory test to measure the experienced driver emotional response of automotive steering wheel vibration

4.3.1 – Laboratory Test Stimuli

For the purpose of consistency, all of the seventeen road surface types that were selected for assessment in the questionnaire survey (shown in figure 4.1), were also assessed in this laboratory experiment. The seventeen road types selected from the Perception Enhancement database of road test measurements also included the recorded steering wheel vibration stimuli ready for testing. For each road surface type a two-minute recording of the steering wheel acceleration had been measured by means of an accelerometer which was rigidly clamped to the surface of the steering wheel at the 60° position (two o'clock position) with respect to top centre, which is the most common grip position adopted by nonprofessional driver's (Gnanasekaran, 2006). The accelerometer had been mounted so as to measure the acceleration in the direction, which was tangential to the steering wheel rotation. For all roads and automobiles the accelerometer type and the mounting clamp used were appropriate for the frequency range from 0 to 300 Hz.

The seventeen steering wheel time histories were all from mid-sized European automobiles which were driven in a straight line over the test roads at a speed which was consistent with the surface type (Department of Transport, 2006). Driving conditions were selected such that they were characterised by significantly different statistical signal properties and that the widest possible operating envelope could be achieved in terms of the steering acceleration root mean square value (r.m.s.), kurtosis value, crest factor value and power spectral density function.

Figure 4.5 presents the same seventeen road surfaces as assessed in the questionnaire study, which had produced the steering wheel acceleration time histories, as viewed from directly above and as seen when driving.

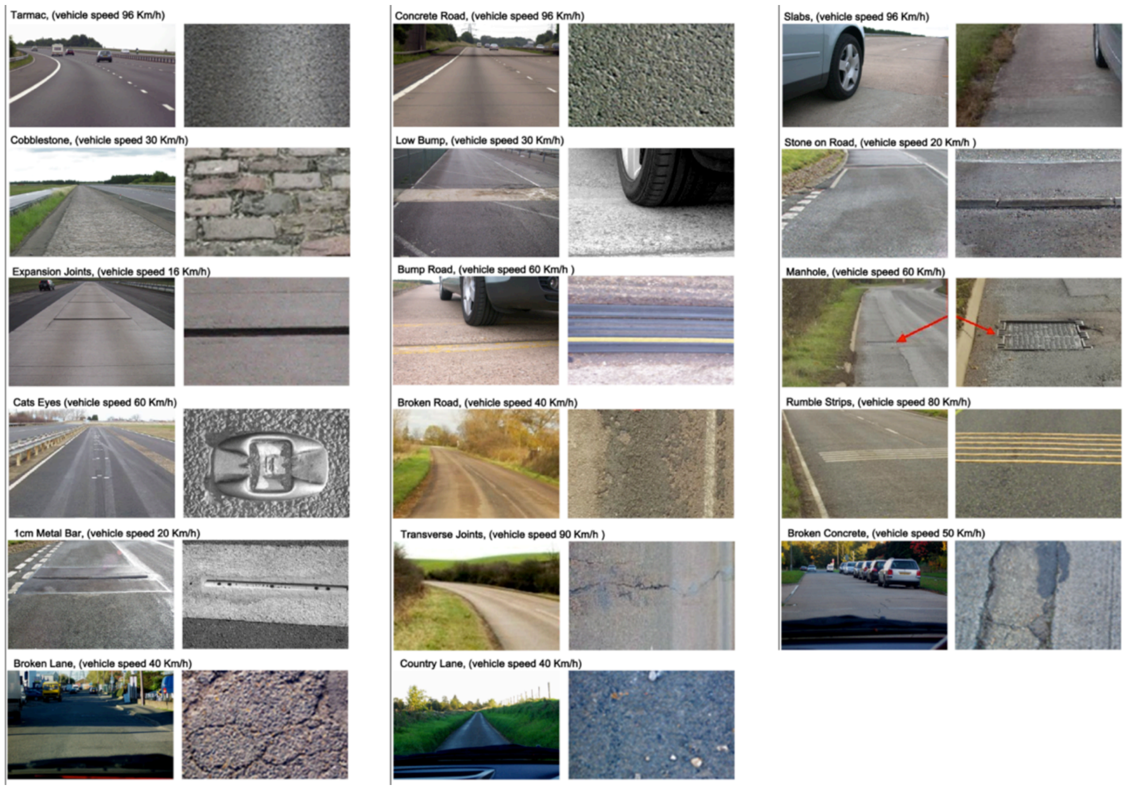


***Figure 4.5** Road surfaces and vehicle speeds whose stimuli were chosen for use in the laboratory tests.*

A short but statistically representative segment of data was extracted from each of the seventeen acceleration time histories (Giacomin et al., 2000). The segments were selected such that the root mean square values, the kurtosis, crest factor value and the power spectral density were close to those of the complete time history. For all driving conditions, a 7-second segment was taken so as to remain within human short term memory (Baddeley, 1997). Since none of the steering wheel acceleration time histories contained significant vibrational energy at frequencies greater than 120 Hz, the decision was taken to apply a bandpass digital Butterworth filter to limit the vibrational energy to the frequency range from 3 Hz to 120 Hz, the lower cut-off value of 3 Hz having been chosen in recognition of the frequency response limitations of the electrodynamic shaker unit of the laboratory test bench, as described below (Figure 4.8.B).

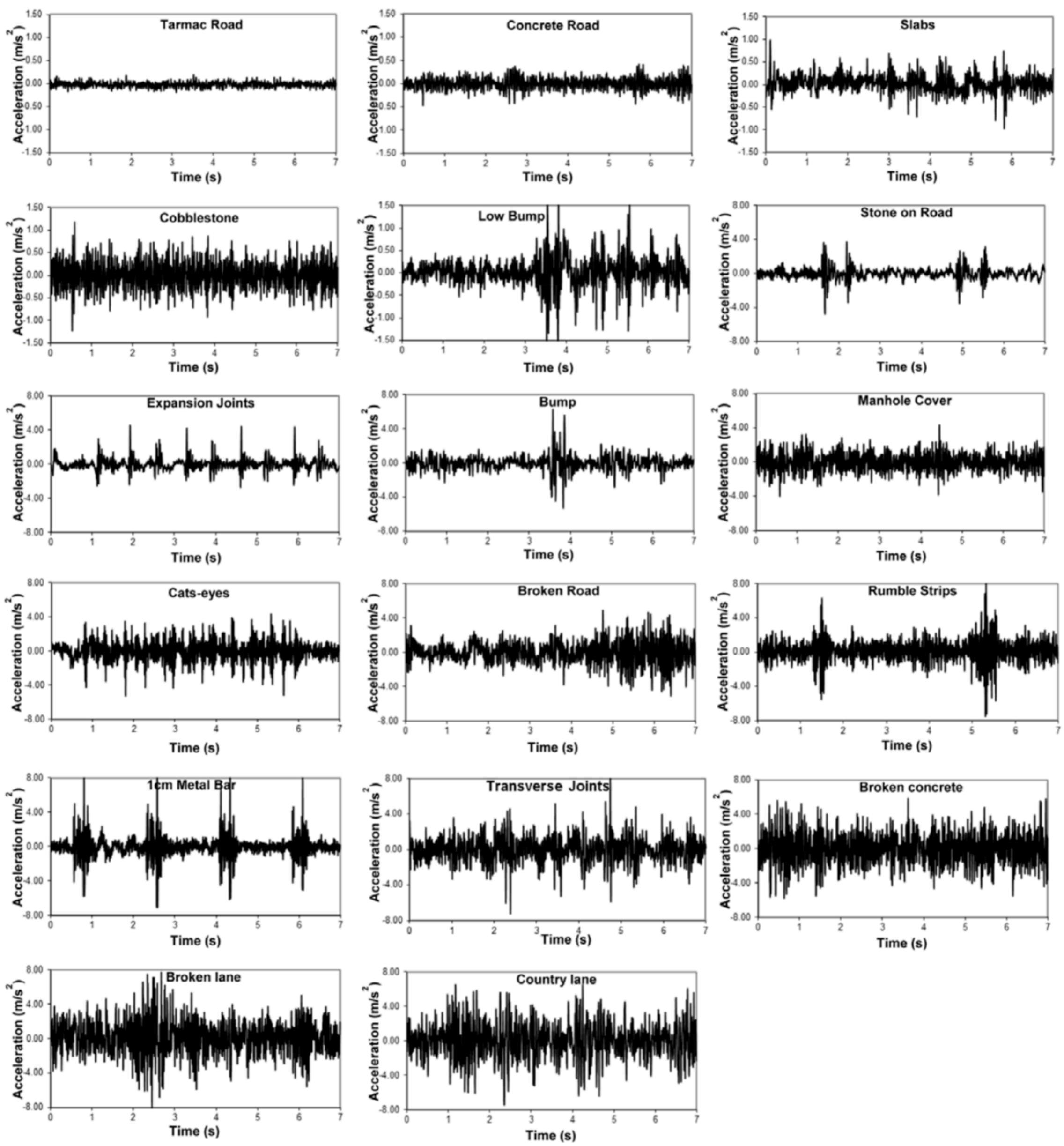


***Figure 4.6** The seventeen steering wheel acceleration time history segments which were extracted from the road test recordings for use as laboratory stimuli.*

Using the T-MON module of the LMS CADA-X software (described in chapter 4.3.2 bellow), signal analysis was carried out to examine and categorise all available road acceleration data. Figure 4.6 presents the resulting time history segments while Figure 4.7 presents the respective power spectral densities.

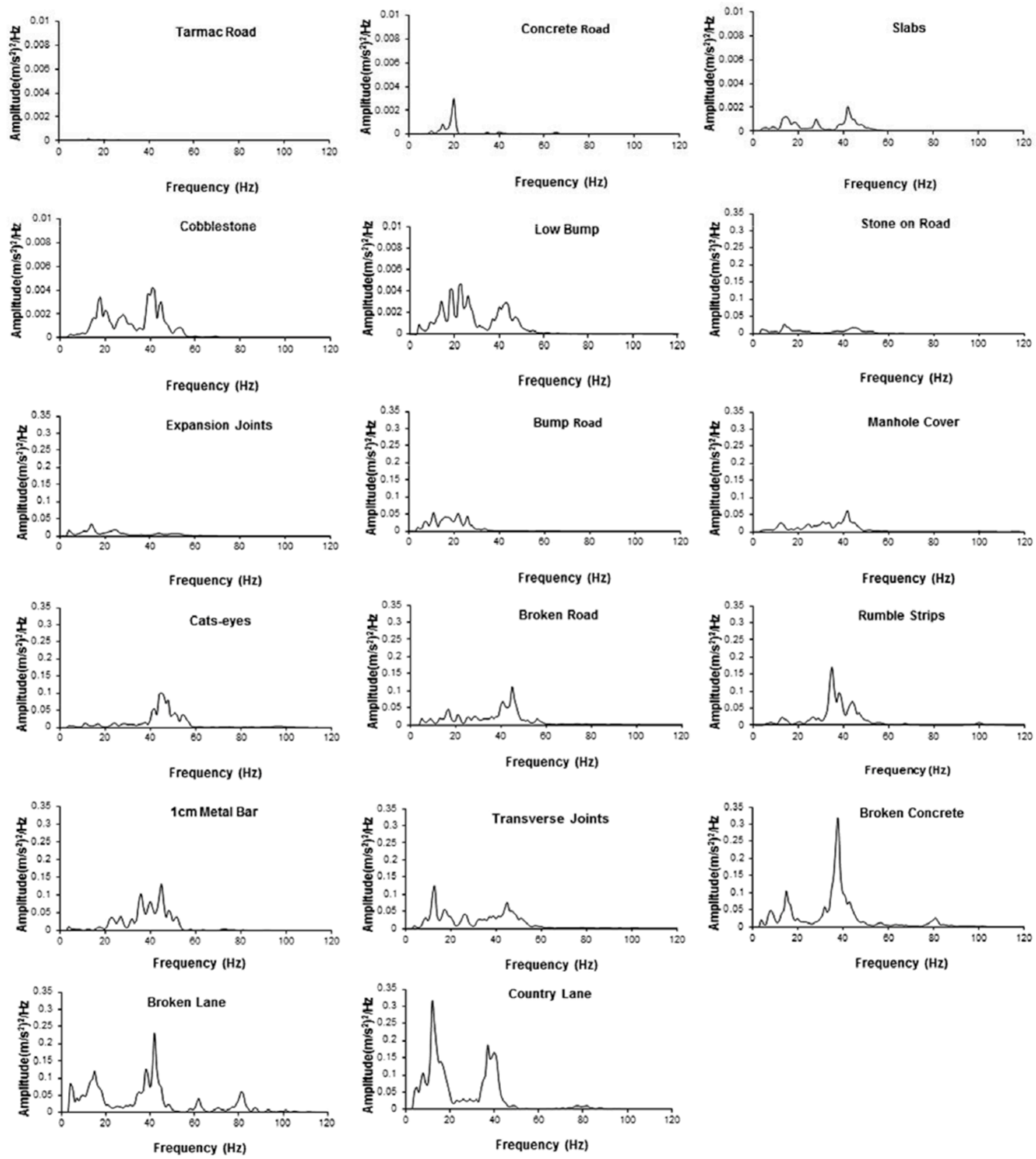


Figure 4.7 *The Power Spectral Densities (PSD) calculated from the seventeen steering wheel acceleration time history segments.*

From Figure 4.7 it can be seen that the steering wheel power spectral densities determined from all the roads and test conditions showed that a significant amount of vibrational energy was present in the frequency range between 10 and 60 Hz, but that vibrational energy was much lower outside this range.

Vibration signals are commonly classified by global signal statistics using the mean, standard deviation, and root-mean-square values, as well as kurtosis and the crest factor, which are the main signal statistics metrics considered in this thesis. The root mean square or quadric mean is associated with the numerical measure of the overall scale of a signal's energy. It is a significant factor especially with haptic stimuli where the energy varies from positive to negative. The value of r.m.s., is determined by calculating the overall area covered by the curve from the zero point whereas the peak depicts the maximum velocity reached by the signal. The Kurtosis statistical parameter indicates the degree of peakedness or flatness of a distribution in relation to the normal Gaussian distribution, which flows in a bell shaped line. A positive value indicates the peaks/ tails are longer than the normal distribution (taller spikes in the signal) where as a negative value indicates that the distributions are shorter than the Gaussian distribution (a smoother/ flatter signal). Crest Factor is taken into consideration to measure the severity of a section of stimuli as it provides information of the spikiness of a stimuli segment, so the higher the spikes within a signal the greater the Crest Factor. The crest factor is calculated by dividing the signal's peak value against its root mean square value, which highlights the signal segments with high activity.

The global statistical properties calculated for the complete original recording over each road surface is presented in Table 4.3. The global statistics table of all 17 signals used shows that the steering vibratory accelerations achieved root mean square values from a minimum of 0.06 m/s^2 for the tarmac road surface to a maximum value of 2.17 m/s^2 for the cat eyes road surface.

__Table 4.3__ Global statistical properties of the steering wheel acceleration time histories for the seventeen road driving conditions which were used as test stimuli in the experiments.

Road Surface Type	*Speed (km/h)*	*r.m.s* vibration level (m/s^2)	Kurtosis (dimentionless)	Crest factor (dimensionless)
Tarmac	96	0.06	3.09	3.42
Concrete	96	0.12	3.45	3.72
Slabs	96	0.19	5.27	5.28
Cobblestone	30	0.28	3.17	4.27
Low Bump	30	0.30	8.05	6.19
Stone on Road	20	0.64	10.99	6.71
Expansion Joints	16	0.69	10.28	5.24
Bump Road	60	0.88	10.15	6.59
Manhole	60	0.99	3.25	4.18
Cats Eyes	60	1.07	4.67	4.47
Broken Road	40	1.22	3.93	4.1
Rumble Strips	80	1.24	7.76	6.4
1cm Metal Bar	20	1.24	17.12	7.32
Transverse Joints	90	1.36	5.11	5.62
Broken Concrete	50	1.71	3.19	3.38
Broken Lane	40	1.81	3.79	4.32
Country Lane	40	1.97	3.43	3.55

4.3.2 – Laboratory Test Facility

The test facility used for this laboratory experiment involved a steering wheel rotational vibration simulator built by the Perception Enhancement Research team, which is shown in figure 4.8.A. The schematic representation of the test bench used is also shown in figure 4.8.B, along with the associated signal conditioning system and the data acquisition system used.

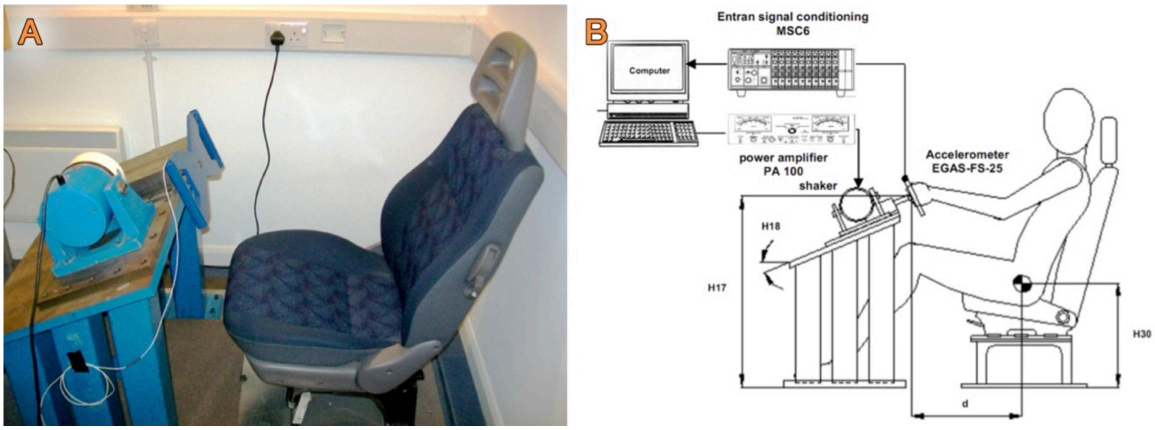


Figure 4.8 *Schematic representation of the steering wheel test rig*

Table 4.4 presents the main geometric dimensions of the test rig used, which are based on data gathered from a small European automobile. The test rig seat was fully adjustable in terms of horizontal position and back-rest inclination as in the original automobile.

Table 4.4 *Geometric dimensions of the steering wheel rotational vibration test rig.*

Geometric Parameter	Value
Steering column angle (H18)	23°
Steering wheel hub centre height above floor (H17)	710 mm
Steering wheel diameter (W9)	325 mm
Steering wheel tube diameter	25 mm
Horizontal distance from H point to steering wheel hub centre (d= L11-L53)	390–550 mm
Seat H point height from floor (H30)	275 mm

The steering wheel itself was 325 mm in diameter, and was manufactured from aluminium. The steering wheel was attached to a steel shaft which was in turn mounted to bearings and connected to an electrodynamic shaker. Rotational vibration was applied by means of a G&W V20 electro dynamic shaker driven by PA100 amplifier. The steering wheel acceleration was measured by means of an Entran EGAS-FS-25 accelerometer attached to the top left side of the wheel and the acceleration signal was amplified by means of an Entran MSC6 signal conditioning unit. Control and data acquisition were performed by means of the Leuven Measurement Systems (LMS) Cada-X 3.5 F software system coupled to a DIFA SCADASIII unit (LMS International, 2002).

The maximum stroke of the test rig shaker unit (±10 mm) limited the maximum achievable acceleration at the steering wheel which, in turn, limited the minimum test frequency to 3 Hz. For frequencies lower than approximately 3 Hz accurate acceleration signals could not be achieved at the rigid steering wheel. The safety features of the rig and the acceleration levels used, conform to the health and safety recommendations outlined by British Standards Institution BS 7085 (1989).

In order to determine the stimuli reproduction accuracy of the test rig facility an evaluation was performed. The procedure evaluated the complete chain composed of the LMS software, the front end electronics unit, the electro-dynamic shaker, the accelerometer and the signal conditioning unit. The accuracy of the target stimuli reproduction was quantified by measuring the r.m.s. difference between the actuated signal and the target signal. Eight participants were used in the pre-test process so as to consider also the possible differences in bench response which are caused by differences in impedance loading on the steering wheel from people of different size. Results suggested that the maximum percentage of error between the r.m.s. acceleration level of the target signal and the actuated signal was found to be less than 5% for all stimuli used in the pre-test.

4.3.3 – Laboratory Test Participants

A total of 30 test participants took part in the study, including university students and staff. A consent form and a short questionnaire (Appendix 3) were presented to each participant prior to testing and information was gathered regarding their anthropometry and health. Gender, age, height, weight and driving experience data were collected, and the participant was requested to state whether he or she had any physical or mental condition that might affect the perception or the emotional response to hand-arm vibration, and whether he or she had smoked or ingested coffee within the 2 hours previous to arriving in the laboratory.

Table 4.5 *Physical characteristics of the group of test participants involved in the laboratory experiments (n=30)*

Characteristics		Mean	Standard Deviation	Minimum	Maximum
Age	**(years)**	25.5	7.7	20.0	54.0
Height	**(m)**	1.7	0.1	1.5	1.9
Mass	**(kg)**	76.4	17.1	47.0	98.0

Table 4.5 presents a basic summary of the physical characteristics of the group of test participants. The group consisted of 25 males and 5 females. The mean values and the standard deviation of the height and weight of the test participants presented in Table 4.5 were near the 50 percentile values for the U.K. driving population (Pheasant and Haslegrave, 2005) except in the case of age, which was somewhat lower than the UK national statistics. Driving experience ranged from 3 years to 25 years with a mean value of 5.6 years. No test participant declared a physical or a cognitive condition, which might affect the perception of hand-arm vibration. All subjects declared themselves to be in good physical and mental health and none declared having smoked or ingested coffee prior to arriving in the laboratory. All had more than two years of driving experience.

4.3.4 – Laboratory Test Protocol

Similar to the questionnaire survey, the self-assessment manikin scale (figure 4.9), with its graphical representation of the human body was used in this laboratory study in order to help participant's rate their expected emotional response of the valence and arousal dimensions. The same Likert format rating scale with values from 1 to 9 to span the range from unpleasant to pleasant to in the case of the valence, and to span the range from calm to excited in the case of the arousal dimension. In the basic form adopted for use in the current study the SAM provides a two dimensional measure of the human emotional state based on the direction and size of the response. The self-assessment scale used in the laboratory experiment was not altered in any way and used as standard.

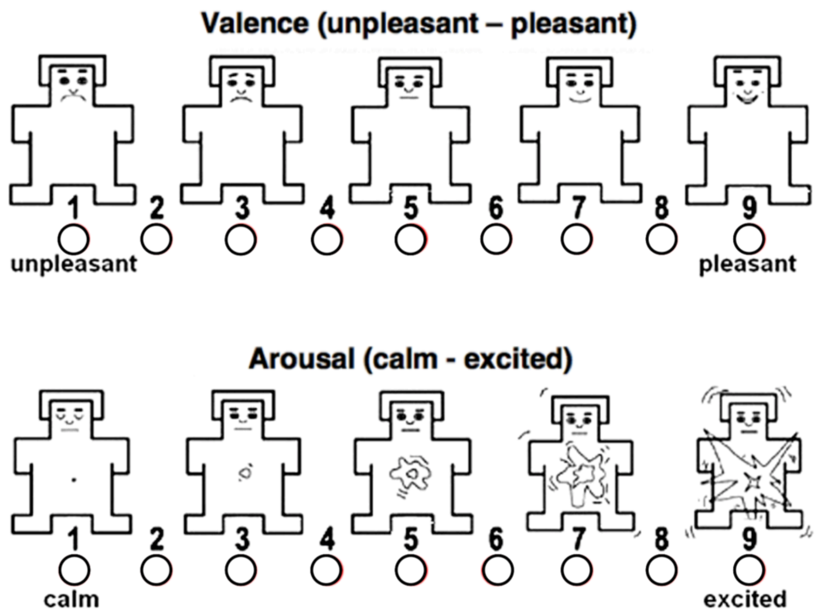


Figure 4.9 *The Self-Assessment Manikin (SAM) used to rate the affective dimensions of emotional valence (top panel) and emotional arousal (bottom panel). (Adapted from Bradley and Lang, 1994).*

Before commencing testing each subject was required to remove any heavy clothes such as coats and to remove any watches or jewellery. They were then asked to adjust the seat position and backrest angle so as to simulate a driving posture as realistically as possible. Since grip type and grip strength (Reynolds and Keith, 1977) are known to effect the transmission of vibration to the hand-arm system, the subjects were asked to maintain a constant palm grip on the steering wheel using both hands. The subjects were also asked to wear ear protectors so as to avoid auditory cues. Room temperature was maintained within the range from 20°C to 25°C so as to avoid significant environmental effects on the skin sensitivity (ISO 13091-1, 2001).

A PC-based software programme running on a HP Pavilion HDX 9000 laptop computer was developed for the purpose of measuring the human emotional response to vibration stimuli. For each test vibration stimulus the dedicated software programme first presented an image of the test road condition for a fixed period of time, then presented the SAM emotional response self-rating scale. The HP Pavilion HDX 9000 laptop had a 20.1 inch wide screen which was set at an inclination of 15° with respect to the vertical. The laptop was positioned on a stand at about 1m ahead such that the centre of the screen was at approximately the eye height of the test participant.

Each of the seventeen stimuli was presented three times to each of the 30 participants for a total of 90 estimates for each test road condition. During each test a series of 7-second steering wheel acceleration stimuli were presented to the participant, using a 10 second gap between each stimulus during which each participant was asked to rate their emotional state of the perceived vibration felt through the steering wheel using the SAM scale (Figure 4.9). Providing participants 10 seconds in which to consider the stimulus, self-reflect on the emotional state produced, and select the two SAM emotional responses (valence and arousal) was found to be appropriate following a pilot test with three individuals. In addition, a total elapsed time of 17 seconds per stimuli also appeared appropriate due to permitting the participant to perform all relevant operations within the confines of human short term memory (Baddeley, 1997). In order to minimize any possible bias resulting from learning or fatigue effects, the order of presentation of the test signals was randomized for each participant. Three preliminary tests, whose data were not analysed, were performed so as to familiarise the participant with the procedure. The automobile speed associated with each stimulus was not provided, and no feedback was provided about the possible correctness of judgement. A complete experiment lasted approximately 35 minutes min for each test participant. The test facility and protocol were reviewed and found to meet University guidelines for good research practice.

4.3.5 – Laboratory Test Results

The experiment results for all 30 participants are shown in Appendix 4, which include every acceleration signal and the subjective ratings of the valence and arousal scales. Table 4.6 presents the mean affective ratings and the standard deviation values obtained across the whole group of 30 participants for the valence and arousal responses to each of the seventeen steering wheel vibration stimuli analysed in this study. A one-factor ANOVA test (Hinton, 1999) was chosen in order to identify significant differences between road conditions for the valence dimension $F(16, 493) = 2.04$ and for the arousal dimension $F(16, 493) = 2.04$. A parametric test was chosen since data were collected using a quantitative rating scale from 1 to 9. The results suggested that all the values for both the valence and arousal ratings of all participants showed statistically significant differences at $p=0.01$ confidence level.

Table 4.6 *Root mean square amplitudes of the unweighted acceleration signals, and corresponding valence and arousal affective ratings (n=30 people) for each of the seventeen road driving conditions used in this study*

Road Surface Type	*Unweighted r.m.s* (m/s^2)	Pleasure rating mean (SD)	Arousal rating mean (SD)
Tarmac	0.06	8.86 (0.4)	1.02 (0.1)
Concrete	0.12	8.72 (0.7)	1.20 (0.5)
Slabs	0.19	8.12 (1.0)	1.52 (0.6)
Cobblestone	0.28	7.70 (1.2)	1.83 (0.9)
Low Bump	0.30	7.59 (1.1)	1.97 (1.0)
Stone on Road	0.64	6.43 (1.1)	2.72 (1.0)
Expansion Joints	0.69	5.73 (1.3)	3.33 (1.3)
Bump Road	0.88	5.14 (1.5)	4.01 (1.8)
Manhole	0.99	6.04 (1.4)	3.19 (1.4)
Cats Eyes	1.07	5.70 (1.8)	3.39 (1.8)
Broken Road	1.22	5.84 (1.6)	3.76 (1.8)
Rumble Strips	1.24	5.60 (1.4)	3.59 (1.5)
1cm Metal Bar	1.24	5.41 (1.5)	3.60 (1.6)
Transverse Joints	1.36	5.43 (1.7)	3.89 (2.0)
Broken Concrete	1.71	4.90 (1.7)	3.92 (1.7)
Broken Lane	1.81	4.07 (1.9)	4.68 (1.9)
Country Lane	1.97	4.37 (2.0)	4.97 (2.3)

As can be seen from the table 4.6, the standard deviation was found to generally increase with increasing test vibration intensity indicating a greater difficulty on the part of the participant to distinguish high vibration intensity stimuli. Another feature that can be observed is that the affective ratings obtained in this study accounted for almost half the dynamic range of the nine-point SAM scale values for both the valence and arousal dimensions. This result would suggest that the set of automotive steering wheel vibration acceleration levels associated to the driving conditions of this study did not elicit either highly unpleasant sensations or excited sensations. In order to investigate how changes in the vibration intensity levels may cause changes in the induced human emotional response to the steering wheel vibration stimuli, the mean affective ratings of valence and arousal were plotted against the unweighted r.m.s. acceleration amplitude of the seventeen test stimuli as shown in Figure 4.10 for the valence ratings and 4.11 for the arousal ratings. The distribution of the data points presented in Figure 4.10 and 4.11 suggests a relatively linear relationship between the vibration intensity and the induced human emotional response.

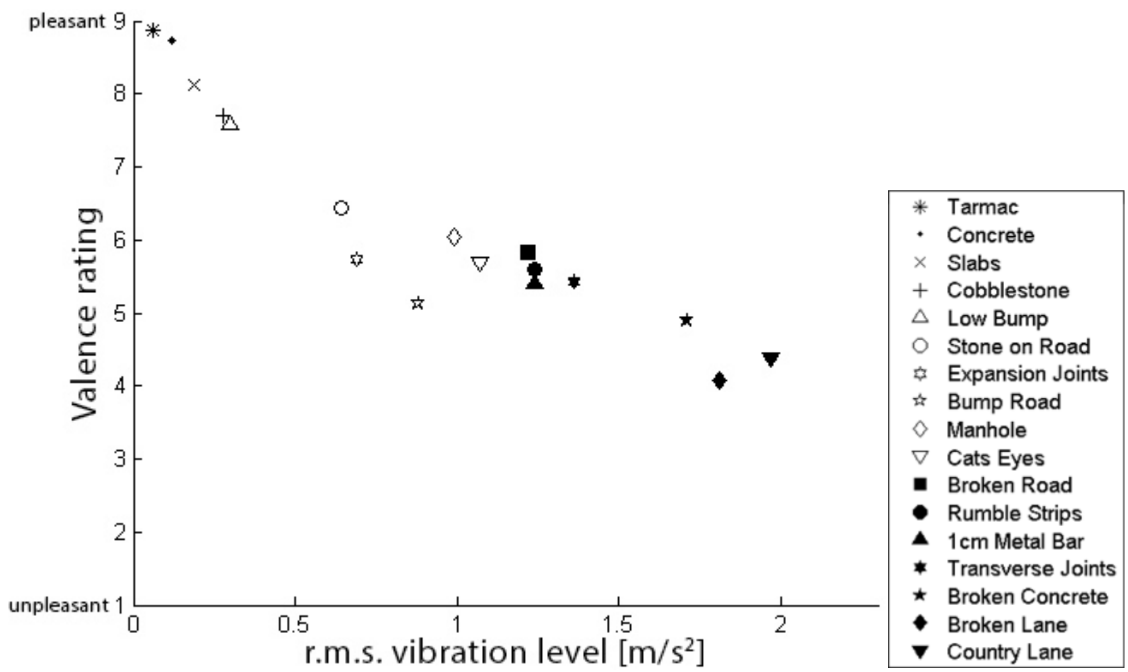


Figure 4.10 *Mean affective ratings of the seventeen road driving conditions obtained for the valence ratings*

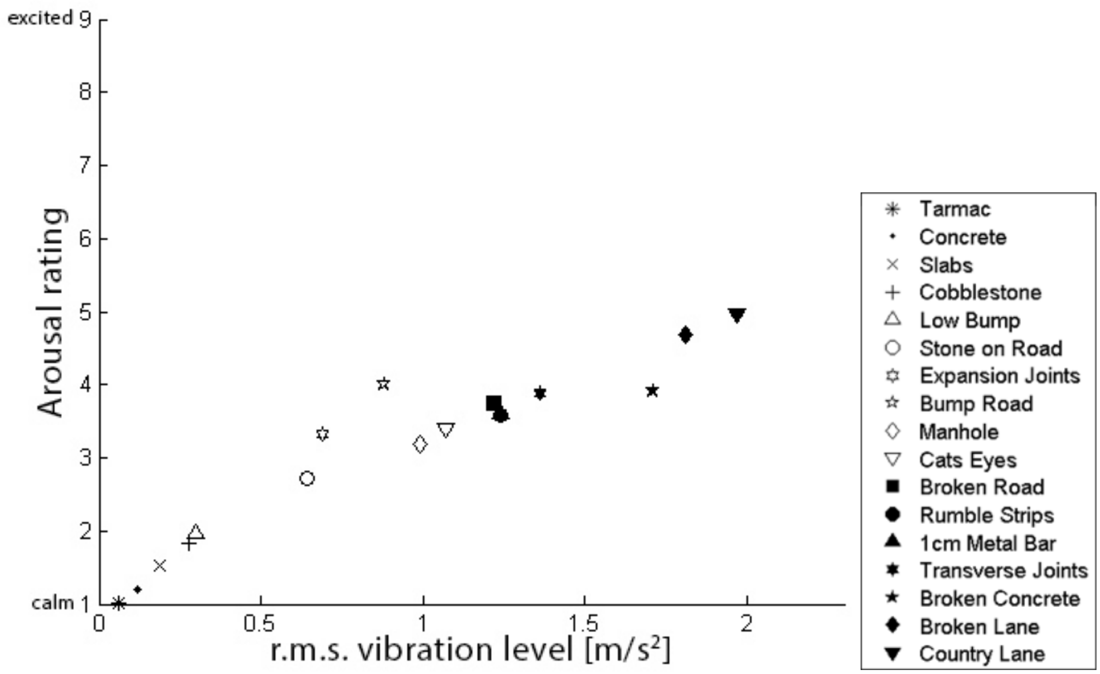


Figure 4.11 *Mean affective ratings of the seventeen road driving conditions obtained for the arousal ratings.*

In order to investigate what form of relationship existed between the valence and the arousal dimensions of the human emotional response to steering wheel vibration, the experimental data were plotted in the two-dimensional affective space defined by the mean valence and arousal ratings of each road driving condition used in this study as shown in Figure 4.12. A regression line was fitted to the data of the valence and arousal ratings by means of least squares regression (Hinton, 1999).

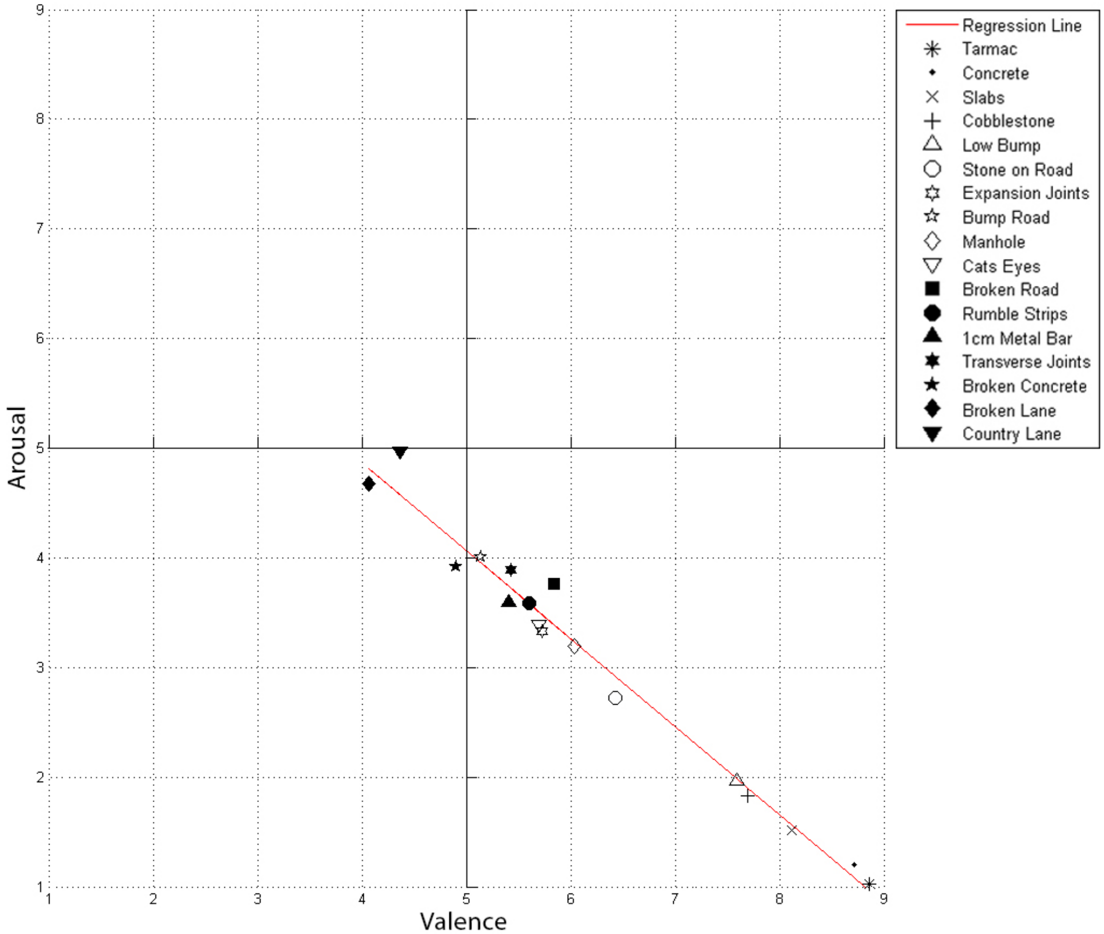


Figure 4.12 *The Two-dimensional affective space defined by the mean ratings of valence and arousal of automotive steering wheel vibration for the seventeen road driving conditions.*

The distribution of the data points in Figure 4.12 confirm the notion that was found in the previous questionnaire survey (Figure 4.3) which suggested that high levels of emotional arousal (excited feelings) of steering wheel vibration are mostly associated with low levels of emotional valence (unpleasant feelings), and that high levels of emotional valence (pleasant feelings) are associated with low levels of emotional arousal (calm feelings) of the vibration. The relationship shown in the two-dimensional affective space for the different road driving conditions would also confirm the results of the current study whereby the differences in the human emotional response may be attributable to the differences in the r.m.s. acceleration values of the steering wheel vibration. In particular, low intensity steering wheel vibration stimuli with acceleration values less than 0.30 r.m.s. m/s^2, such as those of the tarmac, concrete, slabs and low bump road conditions of the present study, elicited high levels of valence and low levels of arousal suggesting thus a more pleasant and calmer emotional response than higher intensity steering wheel acceleration stimuli. Whereas high intensity steering wheel vibration stimuli with acceleration values more than 1.70 r.m.s. m/s^2, such as those of the broken concrete, broken lane and country lane driving conditions, were characterised by low levels of valence and high levels of arousal suggesting thus an unpleasant and aroused emotional response.

4.3.6 – Discussion

The research question addressed in this experiment was which form of correlation may exist between measures of the valence and the arousal dimensions of the human emotional response to steering wheel vibration provided by test participants and the vibration intensity metrics obtained by means of the unweighted r.m.s. values. The results suggest that the affective dimension of arousal is highly dependent on the vibration intensity, and while vibration intensity plays a significant role in eliciting emotional feelings, it is also possible that there are factors other than vibration intensity which influence the human emotional response to steering wheel vibration, such as the presence of high peak events in the steering wheel stimuli. Also, Figure 4.12 shows that when steering wheel vibration stimuli are characterised by similar vibration intensity or similar frequency-band amplitude the levels of emotional response elicited are also similar. For example the rumble strips and 1cm metal bar driving conditions which are both characterised by an acceleration value of 1.24 r.m.s. m/s^2 and by a significant amount of vibrational energy mainly in the range between 25 and 60 Hz and much lower outside, elicited similar levels of emotional valence and arousal.

A comparison between the valence and the arousal dimensions (Figure 4.12) of the human emotional response, suggest that high levels of emotional arousal (excited feeling) of steering wheel vibration are mostly associated with low levels of emotional valence (unpleasant feelings), and that high levels of emotional valence (pleasant feelings) are associated with low levels of emotional arousal (calm feelings) of the vibration.

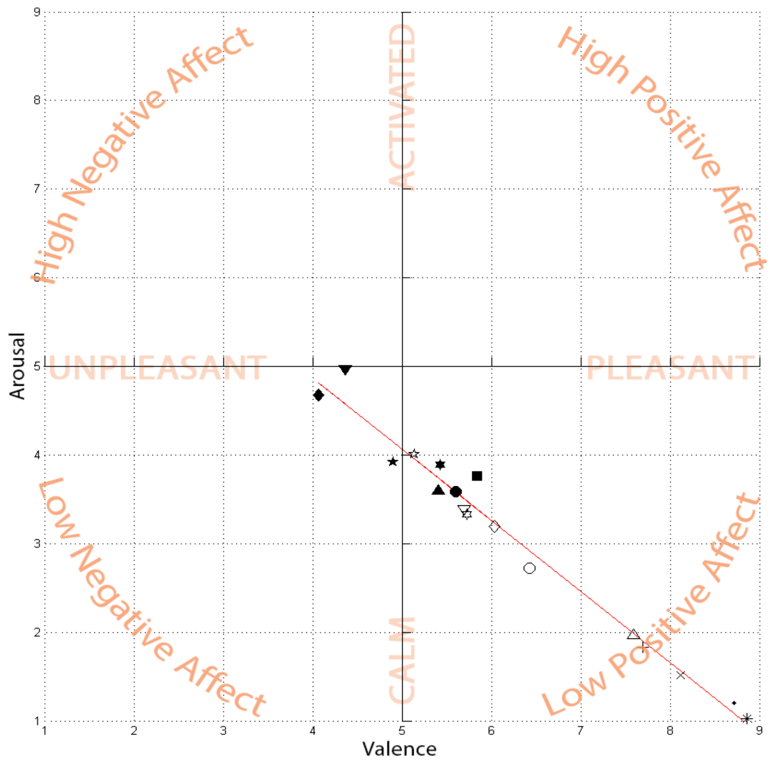


Figure 4.13 *Overlay of the two-dimensional affective space of valence and arousal response over the circumplex model of affect.*

When looking at the data point distribution (Figure 4.12) and comparing it to Russell's, Circumplex Model of Affect (Figure 4.13), it is evident that the regression line falls between a low positive affect moving slightly towards a low negative affect, as no signal falls past the scale value of 5 onto an activated emotional state. The variation in the human emotional response to steering wheel vibration for the valence and arousal affective dimensions is mainly dependent on the vibration intensity of the steering wheel acceleration stimuli. In addition, when vibration stimuli are characterised by similar vibration intensity or similar frequency-band amplitude the emotional response elicited are also similar. Although it is evident that there is a change of affect on the valence and arousal dimensions to driver emotional response to steering wheel vibration, results do not cover the full range of the scale of the two dimensions, which suggest that there may be other emotional dimensions that need to be assessed to fully capture the driver experience of automotive vibration feedback. While difficult to either prove or disprove based only on the current data set, it is possible that there are factors other than vibration intensity which influence the human emotional response to steering wheel vibration, such as the presence of high peak events or high frequency band amplitudes.

4.4 – Comparison between the expected and experienced driver emotional response.

4.4.1 – Discussions of the Survey Study and the Laboratory Test Responses

Given that both the laboratory test and the questionnaire study gathered the human emotional ratings using the same Self Assessment Manikin scale for the same 17 road surface profiles, it was possible to further analyse the two test methods used, allowing for a comparison between the driver's experienced emotional response and the memory based expected response of the valence and arousal dimensions.

In the case of comparison between the human emotional valence and the arousal dimensions of the experienced response form the laboratory test shown in Figure 4.12 to the expected memory based response from the questionnaire survey shown in Figure 4.3, a similar trend can be observed between the two graphs. The similarity of trend in the linear correlations of the two data plots suggests that irrelevant of whether the responses are perceived or memory based, high levels of emotional arousal of steering wheel vibration are mostly associated with low levels of emotional valence, and that high levels of emotional valence are mostly associated with low levels of emotional arousal of the vibration. Although this trend can be seen on both charts, a closer look of the data suggests that a greater linear correlation is observed for the driver's perceived emotional response (Figure 4.12) than for the memory based expected response (Figure 4.3) of the valence and arousal dimensions.

To better visualise the correlation existing between the driver's experienced emotional response to the memory based estimated response of the valence and arousal dimensions, the experimental data were combined and plotted in two-dimensional affective space charts for each of the human emotional valence and arousal scale ratings between the two studies.

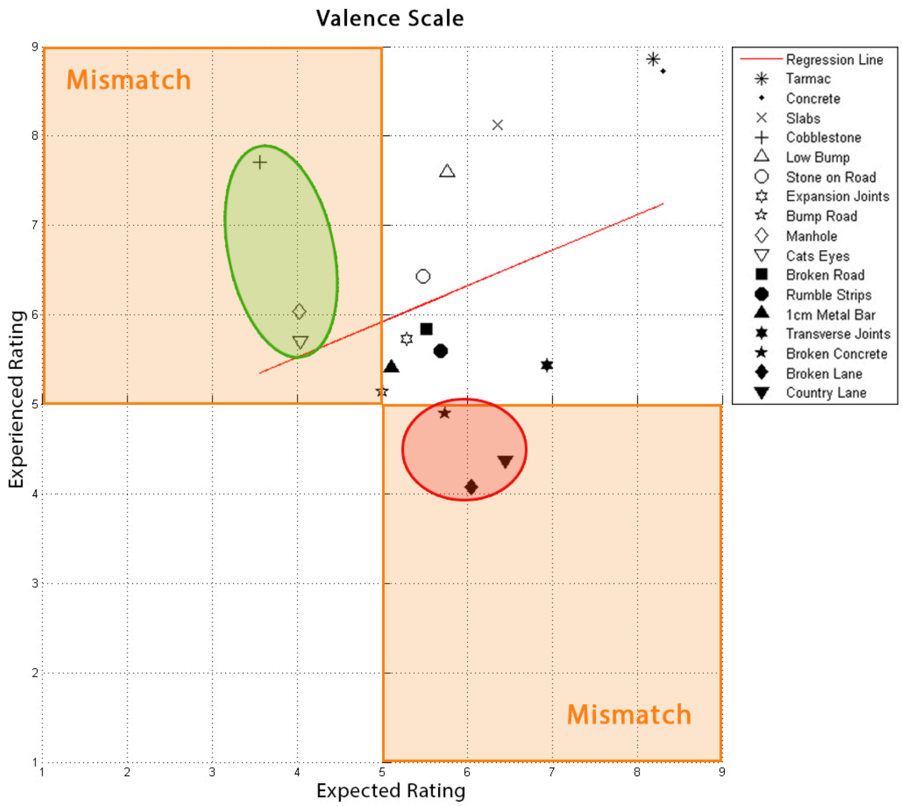


Figure 4.14 *Comparing the valance scales from driver's expected and experienced emotional responses.*

The two dimensional affective space of the valance scale in Figure 4.14 shows the comparison of the drivers expected ratings versus the drivers experienced ratings, which suggests that most of the road surface profiles do tend to match between expectations and experiences, in terms of the emotional rating of the road surface profiles that were expected to be perceived pleasant correlate to the responses gathered from the actual experienced responses from the vibration laboratory test bench. As can be seen from the valence affective chart there are six road surface profiles that did not fall into this category and showed a mismatch between the two studies, for example the three road profiles highlighted in green (Cobblestone, Manhole and Cats Eyes) were expected to have a unpleasant response from memory but in contrast were experienced pleasant in the laboratory test. The other three road surface profiles (Broken Concrete, Broken Lane and Country Lane) which are highlighted in red show the other three road surface types which were expected by participants to be perceived as pleasant feedback but in contrast were perceived unpleasant from actual felt vibrations simulated in the laboratory test.

Figure 4.15 shows the two dimensional affective space of the arousal scale comparing the drivers expected ratings versus the drivers experienced ratings, which suggests that unlike the valence scale affective space (Figure 4.14), sixteen of the seventeen road surface profiles, show a match between the memory based driver expectations and the actual perceived vibration ratings. The cobblestone road surface was the only road profile which fell outside this group, being perceived in the laboratory study as a calm experience which in fact was expected to be perceived as an exciting or highly activated road surface from the questionnaire survey responses.

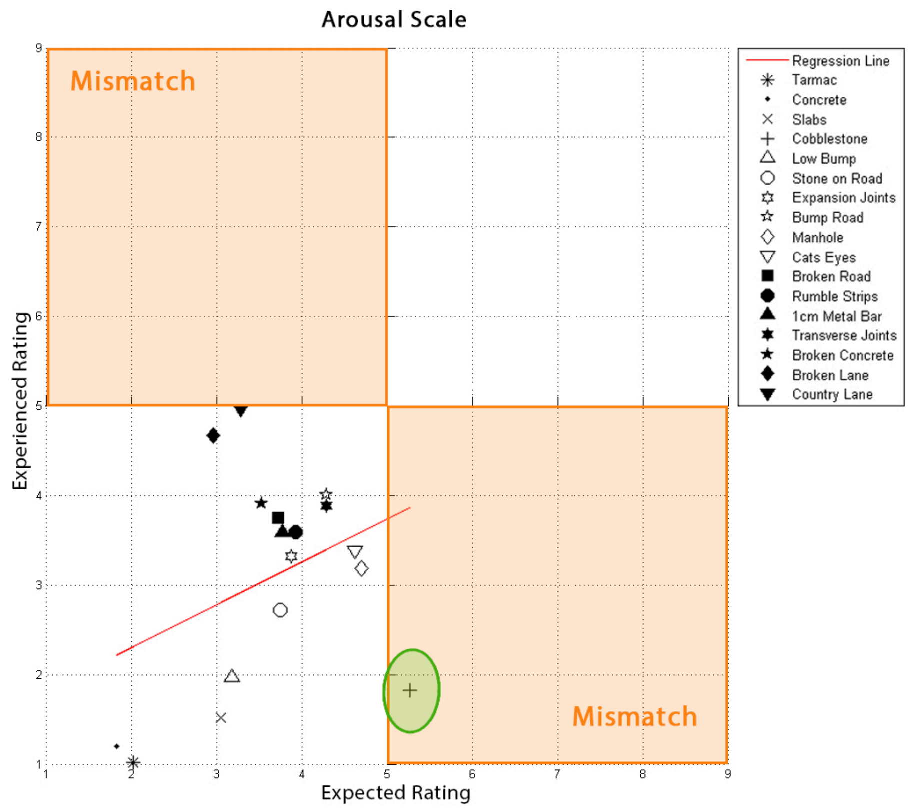


***Figure 4.15** Comparing the arousal scales from driver's expected and experienced emotional responses.*

Comparison of the linear correlations between the two charts (Figure 4.14 and 4.15) of valence and arousal affective two-dimensional spaces, suggest that the valence scale gathered more diverse and wider ranging responses from unpleasant to pleasant dimension, whereas the arousal scale shows a shorter regression line and a grouping amongst most of the roads along the calm and low activation end of the scales.

4.4.2 – Conclusions from the Comparison Study

The questionnaire study described in experiment 1 of this chapter aimed to evaluate what correlation exists between the anticipated measures of the valence and arousal dimensions of the human emotional response and the steering wheel vibration as expected from pictures of road surface types. The results established the mean participant subjective responses of memory-based expected rating of the valence and arousal dimensions for each of the seventeen steering wheel vibration road profiles. The results suggest that pictures of road driving conditions with the least expected surface irregularities are closer related to the pleasant and calm subjective responses, whereas road driving conditions with the most expected surface irregularities are less correlated to the linear correlation of the valence and arousal dimensions, which showed the increased difficult for participants to evaluate and the least similarities between responses.

The laboratory-based test described in experiment 2 of this chapter aimed to provide an understanding on what form of relationship existed between the valence and the arousal dimensions of the human emotional response to steering wheel vibration acceleration intensity. Comparison of the results obtained for the different road driving conditions suggests that the human emotional response of the valence and arousal dimensions is highly dependent on the vibration acceleration intensity of the mean participants ratings. The affective dimension of valance was found to be a decelerating function of the r.m.s. vibration intensity level, whereas the arousal dimension was found to be an accelerating function.

A comparison of the two dimensional affective spaces between the valence and arousal scale for both the laboratory test (Figure 4.12) and the questionnaire survey (Figure 4.3) shows a similarity in the linear correlations of the two data plots which suggests that irrelevant of whether the responses are perceived or memory based, high levels of emotional arousal (excited feeling) of steering wheel vibration are mostly associated with low levels of emotional valence (unpleasant feelings), and that high levels of emotional valence (pleasant feelings) are associated with low levels of emotional arousal (calm feelings) of the vibration. This result seems to be consistent with an underlying bimotivational structure of affective judgements which involve two systems of motivation, each varying towards either a high-arousal pleasant or a high-arousal unpleasant dimension (Greenwald et al., 1989).

Further comparison of the mean participant ratings between the laboratory test and the questionnaire results for each of the emotional affective scales used (Figure 4.14 and Figure 4.15), suggested that most of the road profiles tested which were expected to be perceived pleasant and calm were also experienced pleasant and calm in the laboratory setting, showing a perfect match of driver experiences meeting driver expectation targets. The comparison also highlighted a group of stimuli for the valence dimension, which showed a mismatch between the two studies as they were expected to be perceived as pleasant feedback in the questionnaire survey but in contrast were perceived unpleasant from the felt vibrations simulated in the laboratory test bench. While vibration intensity plays a significant role in eliciting emotional feelings for both expected and perceived responses, there are also other factors which influence the human emotional response to steering wheel vibration such as the presence of high peak events or high frequency band amplitudes.

Considering the research findings shown in Figure 4.14 and Figure 4.15, results suggest that the two basic dimensions of valence and arousal are not suitable to capture and measure the full range of the driver emotional response and that there could possibly be other descriptors essential to measuring all of the aspects associated to the driver emotional response particularly in the context of automotive steering wheel vibration. Mean participant ratings for most of the road surface conditions are mainly scattered within one quarter of each two-dimensional chart, this is especially the case for the arousal dimension, further highlighting the need to define the main criteria of the driver semantic vocabulary to automotive steering wheel vibration, in order to allow the assessment of automotive feedback beyond the two basic emotional dimensions of valence and arousal, as research suggests that to better measure human subjective responses, the descriptive criteria evaluated needs to be directly associated to the context being assessed.

Chapter 5 – Exp.3 – Defining the driver's semantic language of vibration in automotive field study

5.1 – Introduction

Considering the results of the previous chapter, which suggested that although there is a change of affect on the valence and arousal dimensions to driver emotional response of steering wheel vibration, the responses are mainly scattered within one quarter of both two-dimensional charts (Figure 4.14 and Figure 4.15), leading to the conclusion that the two basic emotional dimensions of valence and arousal do not fully describe the driver experience of automotive steering wheel vibration and there may be other emotional dimensions that need to be assessed to fully capture the driver responses of vibration feedback. Therefore this chapter introduces the third experiment carried out, which involving a field study protocol, aims to identify the perceived semantic vocabulary of vibration as defined by drivers when assessing automotive vibration feedback from real road driving scenarios. This chapter focuses on answering the main research question of "***How can the driver emotional response to steering wheel vibration be assessed?***" and to identifying the specific emotional attributes directly associated to driver vibration feedback in relation to the context specific automotive steering wheel vibration. Due to its effectiveness and versatility for measuring attitudes (Himmelfarb, 1993), the semantic differential tool was used in this experiment in order to gather and categorise the adjective descriptors used by drivers to evaluate automotive vibration feedback. The verbalisation task was carried out during a driving field study that helped to gather a large group of vibration descriptors, which were further analysed and put through a merging process in order to be used to build a semantic differential scale.

5.2 – Field Study Test Set-up

The verbal evaluation of a automobiles sensory characteristics and the drivers perceived reactions to these stimuli can be of great importance to automotive manufacturers, so determining the main language descriptors of the semantic space of automotive vibration feedback can be key to carrying out these evaluations. In order to elicit an actual driver vibration related vocabulary, an in-situ field study was conducted in this chapter to gather typical driver responses as extracted from within the context of a typical driving scenario. The field study was conducted on a specified route involving eight road surface types, which included a large selection of various road-driving conditions to elicit a vocabulary relating to a large group of actual road driving scenarios. The selected route was chosen so that not only it covers a large selection of types of road surface conditions but also so that the total length of the experiment route is short enough in order to avoid affecting participant fatigue. Figure 5.1 shows the route each participant drove through during this field study, which included the following road surface conditions: 1-Low bump, 2-Broken road, 3-Country road, 4-Tarmac, 5-Cats eyes, 6-Rumble strips, 7-Cobblestone road, and 8-Large bump.

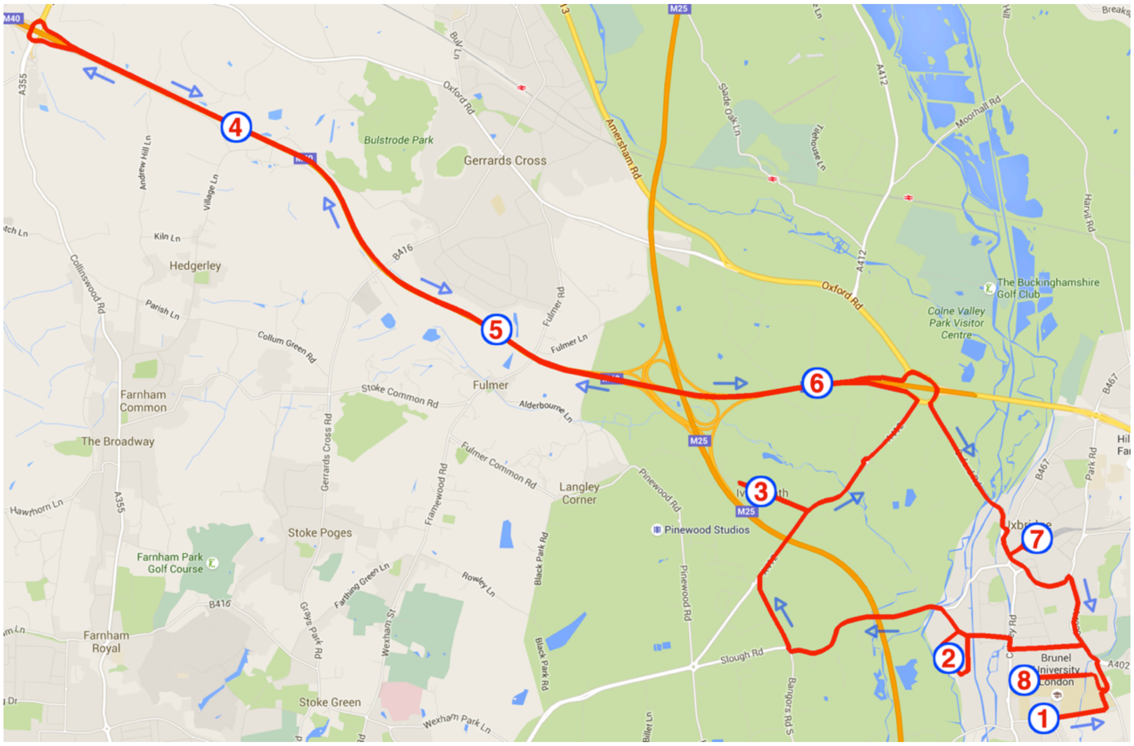


***Figure 5.1** The field study route specified including the eight road surface type conditions used to elicit the automotive steering wheel vibration feedback (Map Source: Google Maps, 2013).*

The road surface events were chosen so that if the participant feels the need to or in the case of an emergency, they had the option to stop the automobile in a safe parking position right after each of the road surface events evaluated. Each of the eight road surface type events were driven in a straight line over the test roads at a speed which was consistent with the surface type (Department of Transport, 2006). Driving conditions were selected such that they were characterised so that the widest possible operating envelope could be achieved in terms of the steering acceleration intensity, and varying event types. A review of the 17 road surface types assessed by the two preliminary studies of chapter 4 was also used to select the route of this field study. Also the choice of some of the road types (broken road, country road, cats eyes and cobblestone) was made to address the mismatch identified in Figure 4.16. The total duration of the whole field study route lasted approximately 1 hour to 1 hour and 30 minutes depending on participant experience and age, and the route started and finishes at the university campus. A close up image of the divers view is presented in Figure 5.2, which includes each of the road surface conditions tested in this field study experiment as seen when driving.

Figure 5.2 *Drivers view of the road surface events, which were chosen for use in the field study (Exp 3).*

Table 5.1 bellow includes the details of each of the chosen events including location, event type, vehicle speed and event duration. Out of the eight events, four, namely low bump, rumble strips, cobblestone and large bump can be classified as containing significant transient events, while the remaining four, namely broken road, country road, tarmac, and cats eyes can be broadly classified as mildly non-stationary signals (Giacomin et al., 2000).

Table 5.1 *Field study event properties of the eight driving conditions used as test stimuli for the verbalisation task.*

Road Surface Type	*Road Location*	*Event Type*	*Speed (km/h)*	Event Duration
1 - Low Bump	Brunel University - South Loop	Transient	30	10s – 20s
2 - Broken Road	Arundel Road	Random	40	30s – 1m
3 - Country Road	Seven Hills Road	Random	40	30s – 1m
4 - Tarmac	M40 Motorway	Random	96	30s – 1m
5 - Cats Eyes	M40 Motorway	Random	60	30s – 1m
6 - Rumble Strips	M40 Motorway	Transient	80	30s – 1m
7 - Cobblestone	Uxbridge - High Street	Transient	30	15s – 30s
8 - Large Bump	Brunel University - North Loop	Transient	20	5s – 10s

For this field study the test participants were asked to use their own automobiles for the route chosen, this was done in order to evaluate the widest possible choice of automobiles that would generate the widest range of vibratory vocabulary. The group of automobiles used involved mostly small to medium sized automobiles with three large sized automobiles. A total of 28 different automobiles were used throughout the field study, with two of them being similar models of different year of manufacture. The maximum year of manufacture of the newest vehicle was 2012 and the lowest (oldest) automobile manufacture year was 1997, the overall mean value of the year of manufacture was 2005. A sample of some of the automobiles used by the participants is shown in figure 5.3 which include different sized automobiles (eg: 1.Toyota Yaris, 2.Vauchall Corsa, 3.Mercedes C-class and Range Rover).

Figure 5.3 *Sample of 4 out of the 30 automobiles used by participants in the field study.*

5.3 – Field Study Participants

A total of 30 test participants took part in the field study, including university students and staff. A consent form and a short questionnaire (Appendix 5) were presented to each participant prior to testing and information was gathered regarding their anthropometry and health. Gender, age, height, weight and driving experience data were collected, and the participant was requested to state whether he or she had any physical or mental condition that might affect the perception or the emotional response to hand-arm vibration, and whether he or she had smoked or ingested coffee within the 2 hours previous to arriving in the laboratory. Table 5.2 presents a basic summary of the physical characteristics of the group of test participants, which consisted of 22 males and 8 females.

Table 5.2 *Physical characteristics of the group of test participants involved in the field study (n=30)*

Characteristics		Mean	Standard Deviation	Minimum	Maximum
Age	(years)	27.3	7.6	21.0	64.0
Height	(m)	1.8	0.1	1.5	2.0
Mass	(kg)	78.1	14.3	46.0	112.0

The mean values and the standard deviation of the height and weight of the test participants presented in Table 5.2 were near the 50 percentile values for the U.K. driving population (Pheasant and Haslegrave, 2005) except in the case of age, which was somewhat lower than the UK national statistics. Driving experience ranged from 2 years to 48 years with a mean value of 8.4 years. No test participant declared a physical or a cognitive condition, which might affect the perception of hand-arm vibration. All subjects declared themselves to be in good physical and mental health and none declared having smoked or ingested coffee prior to arriving in the laboratory. All had a minimum of two years of driving experience.

5.4 – Field Study Protocol

Before commencing testing each subject was required to remove any heavy clothes such as coats and to remove any watches or jewellery. They were then asked to check that the seat position and backrest angle are set to their preferred driving posture. Since grip type and grip strength (Reynolds and Keith, 1977) are known to effect the transmission of vibration to the hand-arm system, the subjects were asked to maintain a constant palm grip on the steering wheel using both hands while driving through the whole route. The total route with all eight road surface events was driven through by each of the 30 participants. During each test event a minimum of 10-second steering wheel stimuli was perceived by the participant, using a minimum of 30 second gap between each stimulus during which, each participant was asked to state that words they would use to describe the perceived vibration felt through the automobile steering. Providing participants 10 seconds in which to consider the stimulus, self-reflect on the sensations and feelings produced by the steering wheel vibration, and to state all the different words they would use to describe the vibrations. After each participant finished responding, they were asked a follow up question which probed whether they could think of any additional words which would describe the same road event. Both of the queries involved open questions, which are known to evoke deeper and more detailed meaningful descriptors regarding the participant's perceptions, opinions and feelings of the felt stimuli. In addition, a total elapsed time of 10 seconds per stimuli also appeared appropriate due to permitting the participant to perform all relevant operations within the confines of human short term memory (Baddeley, 1997). Each test participant was instructed to pay attention at all times to the road ahead, and to not let the questions disturb their ordinary driving operation. In order to minimize any possible bias resulting from learning or fatigue effects, the order of presentation of the road test events was not revealed to any participant. Three preliminary test events, whose data were not analysed, were performed so as to familiarise the participant with the procedure. A GPS satellite navigation device was also used in order to guide the test participants through the designated route. The automobile speed associated with each stimulus was not provided, and no feedback was provided about the possible correctness of judgement. A complete experiment lasted approximately 70 minutes for each test participant. The field test protocol were reviewed and found to meet University guidelines for good research practice.

5.5 – Field Study Results

The field study results for all 30 participants are shown in Appendix 6, which includes each of the transcripts gathered for every road surface event evaluated. As can be seen from the results, some of the participant's vocabulary included many descriptors and some of them did not have a wide range of descriptors. The empty fields are left blank intentionally, and indicate when participants did not mention or think of any descriptors for that specific road event. Each of the participant's transcripts was then analysed in order to extract the meaningful data. Responses with words that included descriptions to the vibration as well as the intensity, such as "a little bit shaky" or "not very smooth" were shortened by removing the "a little bit" or "not very" descriptions so only the vibration related descriptive words were extracted from each response. Multiple worded descriptions were also kept when the whole set was needed to relate to the vibration for example "in-control" or "out-of-control". After all the transcripts were analysed a total of 686 vibrotactile descriptive were extracted from all of the results, many of which were repeated on numerous occasions.

The list of 686 vibrotactile descriptors including many repetitions, was then uploaded onto the NVivo program (software for qualitative data analysis), and a word frequency query was carried out in order to identify the most frequently occurring words throughout the field study transcripts, to combine the repetitions. The NVivo analysis software produced a final list of 153 vibrotactile descriptors, meaning that the field study extracted a total of 153 various descriptive terms of vibration. The full final list of descriptors is presented in table 5.3, which includes the frequency count of each word. This step basically grouped all of the duplicate vibrotactile descriptors and ordered them from the most frequent to the least.

***Table 5.3** The list of 153 vibrotactile descriptors and the frequency of repitition gathered from the field study. (Total word count 686)*

Words	Frequency	Words	Frequency	Words	Frequency	Words	Frequency	Words	Frequency	Words	Frequency
bumpy	66	jerk	6	pleasant	3	subtle	2	light	1	shock	1
shaky	41	mild	6	uneasy	3	unsafe	2	little	1	slippery	1
smooth	41	uneven	6	unpredictable	3	vibration	2	long	1	sound	1
uncomfortable	41	alarming	5	unstable	3	attention	1	lumpy	1	speedy	1
rough	31	alerting	5	unsteady	3	awkward	1	minimal	1	stable	1
harsh	20	calm	5	bad	2	bouncy	1	minor	1	strange	1
strong	17	consistent	5	cautious	2	bubbly	1	moving	1	surprising	1
unpleasant	15	irregular	5	dangerous	2	buzz	1	on-going	1	swinging	1
annoying	13	irritating	5	fast	2	controlled	1	pattern	1	tapping	1
loud	13	jumpy	5	hard	2	crispy	1	perceptible	1	tiny	1
bump	11	rigid	5	hilly	2	different	1	piercing	1	turbulent	1
bumps	11	small	5	humming	2	disturbing	1	quiet	1	under-control	1
powerful	11	stiff	5	instant	2	dominating	1	ramp	1	unnerving	1
sharp	11	sudden	5	jagged	2	easy	1	random	1	unnoticeable	1
wobbly	11	weak	5	jolty	2	extreme	1	rattily	1	unreliable	1
intense	10	aggressive	4	low	2	fair	1	rattling	1	unsettling	1
noisy	9	distracting	4	nice	2	firm	1	regular	1	unsteardy	1
moderate	8	heavy	4	out-of-control	2	good	1	relaxed	1	vibrant	1
scary	8	medium	4	safe	2	grating	1	relaxing	1	vigilant	1
soft	8	noticeable	4	sensitive	2	hitting	1	repetitive	1	wafty	1
comfortable	7	shaking	4	settling	2	hum	1	rougher	1	warning	1
jerky	7	abrupt	3	severe	2	immediate	1	rugged	1	wavy	1
comfy	6	alert	3	shake	2	in-control	1	rumble	1	weary	1
constant	6	aware	3	shocking	2	inconsistent	1	rumbly	1		
gentle	6	humpy	3	slow	2	intermittent	1	seamless	1		
high	6	jittery	3	steady	2	jutting	1	secure	1		

As can be seen from the table, words such as bumpy, shaky, smooth, uncomfortable, and rough were amongst the most mentioned descriptors, whereas on the other side of the table includes the 72 words that were only mentioned once. A word cloud (figure 5.4) was created of the final list of descriptors, which helped visualise the results including the significance of each of the descriptors. The scale of each word is dependent on the frequency of the descriptor, so the largest words are the most frequent and the smallest font shows the descriptors mentioned only once. For example the bumpy descriptor had a word frequency count of 66, which is shown as the largest in the word cloud. The following most frequent descriptors from table 5.3 are shaky, smooth and uncomfortable, all of which had a frequency count of 41, and all of which are presented in the word cloud (figure 5.4) the same font size.

Figure 5.4 *Word cloud of the 153 vibrotactile descriptors gathered from the field study.*

5.6 – Vibrotactile Descriptors Merging Process

A merging process based on Osgood's et al., (1957) suggestions was carried out on the full list of 153 vibrotactile descriptors, in order to further condense the gathered vocabulary, to extract a more manageable list of descriptors for identifying the key vibration assessment scale (criteria). The merging process of the gathered descriptors involved various steps and was a complex procedure, and to better visualise this, a dendrogram style tree map was created showing the transfer path of each of the 153 descriptors and their convergence into the final merged list. A dendrogram was chosen due to its efficiency in illustrating the arrangement of a clustering or merging process of a large number of variables. The dendrogram is shown in appendix 7, and the full merging process is described bellow in further detail including information on how to follow or read the dendrogram paths of each of the 153 descriptors.

In order to follow the paths of the descriptors in the dendrogram, figure 5.5 shows an example of three descriptors. Bump and bumps were joined together as bumps is just the plural term of bump, and this is shown by the transfer path starting from the bumps descriptor bending and joining to the bump flow path main line. After which the bump main flow path joins to the bumpy flow path. The choice of which descriptor merged into the which other descriptor was based on the word frequency count rating of each descriptor, in this case bump and bumps merged into the bumpy descriptor as it was stated more often by participants.

Figure 5.5 *Example of the visualisation of dendrogram merging paths.*

So the flow paths that start from the left of the page and end all the way to the right of the page are considered as main descriptors, which other descriptors merged into, and all of the descriptor paths that bend towards a horizontal direction indicate the sub descriptors, which were merged into others.

The first step of the merging process involved matching the synonyms within the list of descriptors grouping them together. Synonyms are defined as words which mean exactly or nearly the same as another word. A thesaurus was used In order to find the synonyms between descriptors, as stated by Peter M. Roget (1952), the thesaurus helps users “to find the word, or words, by which [an] idea may be most fitly and aptly expressed". In essence grouping all of the descriptors, which associate to one another. The second step of the merging process was a continuation of the grouping method witch combined all of the antonyms or as referred to in semantics ‘opposites’ or ‘direct opposites’ of the remaining descriptors. This step was shown in the same way on the dendrogram as the first step and a thesaurus was also used to find the antonyms. Finally the last step of the merging process involved removing or ignoring all the remaining descriptors that were only used once by the participants in the field study, so all of the remaining descriptors with a frequency rating of 1 were removed.

From the list of 153 descriptors, all 21 of the descriptive words coloured in red on the right side of the dendrogram (Appendix 7), highlight the descriptors that had a frequency rating of 1 that were ignored. Whereas all of the 16 verbal descriptors coloured in green, highlight the remaining most frequent descriptors of the list that were considered further. The descriptors on the right of the dendrogram which are coloured grey, represent the descriptors which had a lower frequency response rating to the green descriptors and that were not considered for the final list of descriptors.

After the elimination steps, the descriptors were considered further to select a smaller group from the remaining list and based on their frequency rating and their relevance to assess automotive vibration feedback a final list of 12 descriptive words was chosen. The green arrows on the dendrogram point to the 12 final chosen descriptive words, which include: aggressive, alarming, bumpy, comfortable, irregular, out-of-control, pleasant, powerful, rough, safe, sharp, and slippery.

In addition to these 12 vibrotactile descriptors, the acceptability descriptor was added to the list as it was considered an important criteria for measuring vibration. This importance of the characteristic of acceptability of vibration is evident in many publications including various vibration specific BS and ISO publications, and also various NVH related papers (Champagne, 2000). With this addition of the acceptability descriptor, the final list of the chosen 13 descriptor was used to create the finished vibration measurement scale.

In order to develop the semantic differential scale, each of the 13 descriptors was paired up with its direct opposite or polar adjective (opposite-meaning term), and a 5 point liker scale was used for each of the descriptive pairs marked with: Extremely, Moderately, Neither, Moderately, and Extremely from one end of the scale to the other.

The final Driver Emotional Semantic scale, which includes the thirteen semantic descriptors, developed in this chapter is shown in figure 5.6, which was created for measuring the driver subjective emotional response specific to the context of automotive steering wheel vibration. The scale features the driver semantic vocabulary with the most frequent attributes used to describe perceived automotive steering wheel vibration of different road surface types.

Semantic Differential Scale

	Extremely	Moderately	Neither	Moderately	Extremely	
aggressive	○	○	○	○	○	calm
alarming	○	○	○	○	○	unalarming
comfortable	○	○	○	○	○	uncomfortable
out-of-control	○	○	○	○	○	in-control
pleasant	○	○	○	○	○	annoying
powerful	○	○	○	○	○	weak
safe	○	○	○	○	○	not-safe
acceptable	○	○	○	○	○	unacceptable
bumpy	○	○	○	○	○	even
regular	○	○	○	○	○	irregular
rough	○	○	○	○	○	smooth
sharp	○	○	○	○	○	dull
slippery	○	○	○	○	○	grippy

Figure 5.6 *Final Driver Emotional Semantic scale developed from the field study.*

When considering the Self Assessment Manikin scale and comparing the two basic dimensions of valence and arousal to the semantic descriptors gathered in this field study, it is evident that the two assessment dimensions of Pleasant - Unpleasant and Calm - Exited are also assessed by the Driver Emotional Semantic scale (Pleasant - Annoying and Calm – Aggressive). Although different terminology is used for the direct polar opposite of each descriptor, Osgood et al., (1957) stated that not only the descriptors change according to the context assessed but also the polar opposites of each descriptor could also change when assessing the subjective language used in a different context. Considering the greater number of the descriptive pairs assessed by the Driver Emotional Semantic scale as opposed to the Self Assessment Manikin scale used in the previous studies, it can be determined that the newly developed Driver Emotional Semantic scale should capture most if not all of the possible variation of driver subjective responses associated to automotive steering wheel vibrations.

5.7 – Field Study Conclusions

A field study was carried out with 30 participants, which gathered the emotional semantic vocabulary of vibration as defined by drivers when assessing automotive vibration feedback from various road surface types. The verbalisation task generated a total of 153 different vibrotactile descriptors, which were analysed and put through a merging process in order to condense into a more manageable size. A map of the merging process was created and a list of 12 descriptors was extracted which included: aggressive, alarming, bumpy, comfortable, irregular, out-of-control, pleasant, powerful, rough, safe, sharp, and slippery, vibrotactile descriptors. Due to its importance in assessing vibration characteristics, the ‘acceptability’ descriptor was also included in the final list creating a total of 13 vibration descriptive terms. A semantic differential rating scale with 5 point Likert type scale was developed using the final list of 13 descriptors collected from this field study. Due to the greater number of descriptive pairs identified and the scale dimensions being specifically associated to automotive vibrations, the new Driver Emotional Semantic scale developed, should measure with greater accuracy the driver response to automotive steering wheel vibrations. To test the Driver Emotional Semantic scale the following study was carried out (Chapter 6) in order to assess the consistency of its reliability of the assessment criteria (descriptive pairs) for measuring driver subjective responses to automotive steering wheel vibrations.

Chapter 6 – Exp.4 – Assessing the reliability of the driver emotional semantic scale in field test

6.1 – Introduction

This chapter presents the second field study (Experiment 4), which aims to measure the driver's emotional response to the steering wheel vibration using the thirteen semantic descriptors obtained in Chapter 5, and to identify if these thirteen semantic descriptors are reliable when measuring the vibratory steering wheel feedback across three different automotive segment types. The Driver Emotional Semantic scale developed in chapter 5 was used in order to measure the driver's subjective response to real-time automotive steering wheel vibration feedback felt whilst driving over eight different road surface types. A factor analysis method was carried out on the participant's judgements of automotive steering wheel vibration, in order to discover the dimensionality of the semantic descriptors, more specifically to categorise the factors which together account for the majority of the variance between the results.

6.2 – Field Study Test Set-up

This field study was set up in order to further define the driver's semantic language of automotive steering wheel vibration into a more condensed list of descriptors that covers all or most of the variability in the results of the drivers emotional vocabulary. As the semantic differential technique aims to capture the meanings/ vocabulary behind the perceived attitudes within many specified contexts, this study involved an in-situ field experiment to capture the verbal characteristics as described by drivers while assessing real time vibration feedback felt within the context of a real driving scenario. In simpler terms the field study aimed to measure the ratings from the thirteen descriptors and extract the key descriptors most relevant to the specified context of real driving scenarios. This field study involved the measurement of the 13 verbal descriptors (Driver Emotional Semantic rating scale) identified by participants in order to define the felt automotive steering wheel vibration feedback. Similar to the first field study in the previous chapter, this field study also included a specified route involving eight different road surface types. Although this study took place in the same location as in the previous field study, the route was slightly adjusted for two reasons; the first reason was to shorten the overall length of the driving route, as the previous study was lengthy at times for some participants and this would allow for a larger number of participants to be tested. The second reason for the driving route change was to include more of a variation between the chosen events for the assessed vibration feedback, as in the previous field study some participants stated that the cats eyes and the rumble strips were very similar, some of which struggled to try and think of additional words, or just repeated the same descriptors for both of the roads. The cats eyes road surface event was removed in this study and a new road event was introduced which was included a local city street. Figure 6.1 presents the full route designated for all participants of this study, which included the following road surface conditions: 1-Low bump, 2-Broken road, 3-Country road, 4-Tarmac, 5-Rumble strips, 6-City Street, 7-Cobblestone road, and 8-Large bump.

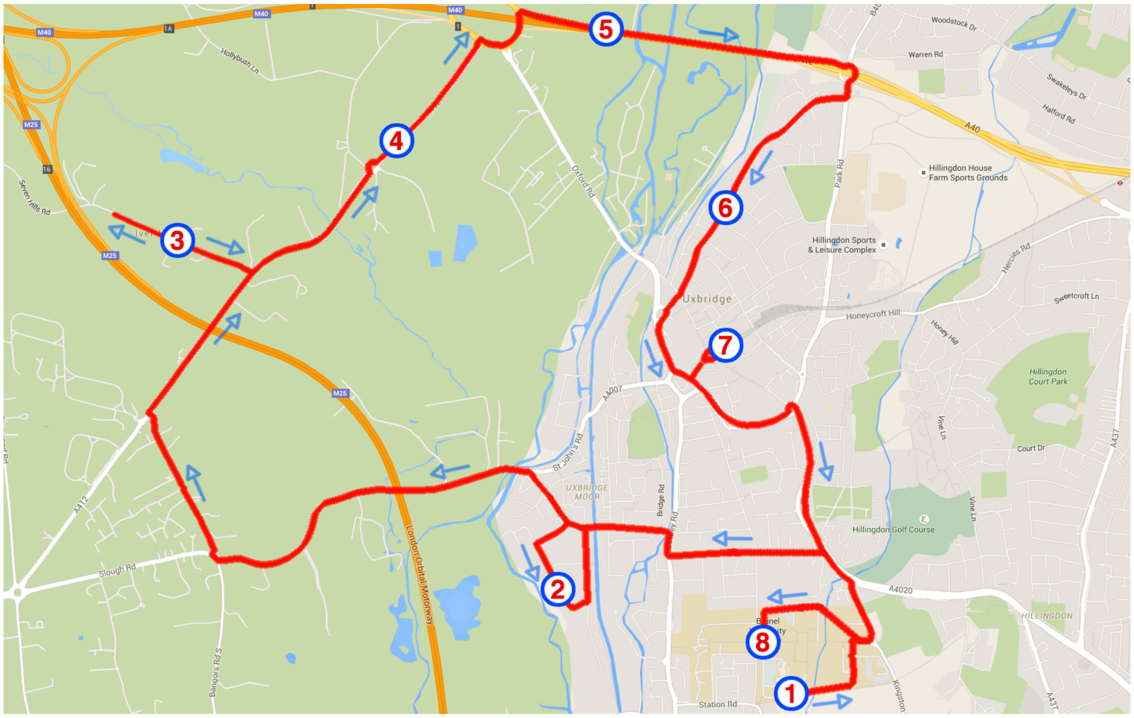


***Figure 6.1** The road study route specified including the eight road surface type conditions used to evaluate the automotive steering wheel vibration feedback (Map Source: Google Maps, 2014).*

As in the previous study, the participants had the option to stop the automobile in a safe parking position right after each of the road surface events evaluated, and each of the eight road surface type events were driven in a straight line at a speed which was consistent with the surface type (Department of Transport, 2006). The field study route driving conditions were readjusted in order to shorten the total duration of the whole field study route to approximately 45 minutes to 1 hour and so also the widest possible operating envelope could be achieved in terms of the steering acceleration intensity and varying event types. The shorter duration of the changed route is clear when comparing figure 6.1 to figure 5.1, as it is clear the distance covered in this study is significantly shorter. A close up image of the drivers view is presented in Figure 6.2, which includes each of the road surface conditions tested in this field study experiment as seen when driving. Each of the road event numbers corresponds to the numbering on the route map in figure 6.1.

Figure 6.2 *Drivers view of the eight road surface events chosen for use in the field study (Exp 4).*

Table 6.1 shows the details of each of the chosen events including location, event type, vehicle speed and event duration. As in the previous field test, four road events can be classified as transient (low bump, rumble strips, cobblestone and large bump) and four can be classified as random (broken road, country road, tarmac, and city street) (Giacomin et al., 2000).

Table 6.1 *Field study event properties of the eight road surface types used as test stimuli for the measurement task.*

Road Surface Type	*Road Location*	*Event Type*	*Speed (km/h)*	Event Duration
1 - Low Bump	Brunel University - South Loop	Transient	30	10s – 20s
2 - Broken Road	Arundel Road	Random	40	30s – 1m
3 - Country Road	Seven Hills Road	Random	40	30s – 1m
4 - Tarmac	A412 Denham Road - M40	Random	96	30s – 1m
5 - Rumble Strips	Denham Roundabout - M40	Transient	80	30s – 1m
6 - City Street	B467 Harefield Road	Random	40	30s – 1m
7 - Cobblestone	Uxbridge - High Street	Transient	30	15s – 30s
8 - Large Bump	Brunel University - North Loop	Transient	20	5s – 10s

This field study involved the assessment of the automotive steering wheel vibration feedback elicited from a selection of six automobiles, two automobiles each chosen from three different automotive segment groups. The three segments included, Segment A for small sized automobiles, Segment B for medium sized automobiles and Segment C for large sized automobiles. Details from each of the six automobiles used in this study are presented in table 6.2, which include the make, model, year, automobile type and gross weight at time of manufacture, as well as images of each automobile used.

__Table 6.2__ Automotive properties of each of the six automobiles used as test stimuli for this filed study.

Automotive Class	Automobile Model & Make	Model Year	Automobile Type	Automobile Weight	Image
Segment A	Renault Clio 1.5	2008	Small Hatchback	1525 kg	
	Volkswagen Polo 1.9	2009	Small Hatchback	1650 kg	
Segment B	BMW 1 Series 2.0	2008	Medium Hatchback	1830 kg	
	Volkswagen Passat 1.9	2009	Small Saloon	2060 kg	
Segment C	Mercedes E Class 2.2	2005	Medium Saloon	2140 kg	
	Audi A5 2.0	2012	Medium Saloon	2310 kg	

The six automobiles used are Renault Clio, Volkswagen Polo, BMW, 1 Series, Volkswagen Passat, Mercedes E Class and Audi, A5. Although the options of automobiles available for use in this field study was limited, as they were borrowed from friends and family, the chosen six automobiles were selected in order to include a wide variety of small to medium overall automobile sizes. As can be seen in table 6.2, the overall weight of the automobiles ranges from 1525 to 2310 kgs. The maximum year of manufacture of the newest automobile used was 2012 and the lowest (oldest) automobile manufacture year was 2005. Each of the selected automobiles was checked that they had been regularly maintained and serviced, and that none of them included any aftermarket modifications or malfunctions.

6.3 – Field Study Participants

A total of 120 test participants took part in this study, with each of the six selected automobiles being evaluated by 20 different participants. A consent form and a short questionnaire (Appendix 8) with further details about the field study was given out to each participant, in order to get written consent, indicating their acceptance or withdrawal from the study and to gather additional driver information such as physical anthropometric characteristics (age, height, weight, gender), or if they had a condition that may affect the field study results (regularly worked with vibrating equipment, medical conditions that can impair perception of feedback or ingestion of alcohol or coffee prior to testing).

Table 6.3 *Physical characteristics of the group of test participants involved in the field study (n=120)*

Characteristics		**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
Age	**(years)**	27.5	8.9	20.0	55.0
Height	**(m)**	1.7	0.1	1.5	2.0
Mass	**(kg)**	77.5	14.9	52.0	120.0

Table 6.3 presents a basic summary of the physical characteristics of the group of test participants, which consisted of a total of 85 males and 35 females. The mean values and the standard deviation values of the height and weight of the 120 test participants presented in Table 6.3 were near the 50 percentile values for the U.K. driving population (Pheasant and Haslegrave, 2005) except in the case of age, which was slightly lower than the UK national statistics. Driving experience ranged from 2 years to 45 years with a mean value of 8.2 years, the newest driver having a minimum of two years experience. No test participant declared a physical or a cognitive condition that might affect the perception of hand-arm vibration. All subjects declared themselves to be in good physical and mental health and none declared having smoked or ingested coffee prior to arriving to the university.

6.4 – Field Study Protocol

In order to identify the key semantic vibratory descriptors associated with the driver emotional response to the felt steering wheel vibration feedback, the semantic differential scale (Figure 6.3) was used to measure the participants subjective ratings of each of the eight road surface types evaluated. The driver emotional semantic scale allowed the gathering of participant ratings for each semantic descriptor (namely: acceptable/ unacceptable, aggressive/ calm, alarming/ unalarming, bumpy/ even, comfortable/ uncomfortable, irregular/ regular, out-of-control/ in-control, pleasant/ annoying, powerful/ weak, rough/ smooth, safe/ not-safe, sharp/ dull, and slippery/ grippy), so as to further analyse the results and identify the key semantic dimensions accounting for the majority of the variability within the driver responses of automotive vibration feedback. Alongside each of the thirteen descriptive pairs of the semantic differential scale, a 5 point Likert scale was used to guide participants to provide their ratings. For example to respond to the first descriptive pair ('aggressive' or 'calm') the test participant could select either "extremely aggressive", "moderately aggressive", "neither", "moderately calm" or "extremely calm". In order to minimize any possible bias resulting from learning or fatigue effects, the order of descriptive pairs was presented in a random order to each participant.

Semantic Differential Scale

	Extremely	Moderately	Neither	Moderately	Extremely	
aggressive	○	○	○	○	○	calm
alarming	○	○	○	○	○	unalarming
comfortable	○	○	○	○	○	uncomfortable
out-of-control	○	○	○	○	○	in-control
pleasant	○	○	○	○	○	annoying
powerful	○	○	○	○	○	weak
safe	○	○	○	○	○	not-safe
acceptable	○	○	○	○	○	unacceptable
bumpy	○	○	○	○	○	even
regular	○	○	○	○	○	irregular
rough	○	○	○	○	○	smooth
sharp	○	○	○	○	○	dull
slippery	○	○	○	○	○	grippy

***Figure 6.3** Driver Emotional Semantic scale used to measure participant responses in road test.*

Before starting each field experiment, the test participants were required to remove any heavy clothes such as coats and to remove any watches or jewellery that may impair their perception of the steering wheel vibrations. Participants were then asked to adjust the seat position and backrest angle so as to best replicate their regular driving posture in the most comfortable position. Since grip type and grip strength (Reynolds and Keith, 1977) are known to effect the transmission of vibration to the hand-arm system, the subjects were asked to maintain a constant palm grip on the steering wheel using both hands throughout the entire study route. The engine of each automobile was warmed up for at least 20 minutes before the test in order to ensure optimum running condition and temperature. The cabin temperature was maintained within the range from 20°C to 25°C so as to avoid significant environmental effects on the skin sensitivity (ISO 13091-1, 2001).

The test route (Figure 6.1), with the eight road surface events, was driven through by 20 participants for each of the six automobiles tested. During each test event a minimum of 10-second steering wheel stimuli was perceived by the driver, using a minimum of 120 second gap between each stimulus during which, each participant was asked rate the perceived vibration felt through the automobile steering for each descriptive pair read aloud to them. Providing participants 120 seconds in which to consider the stimulus, self-reflect on the descriptor ratings, and select the position of each descriptive pair, was found to be appropriate following a pilot test with five individuals. After each participant finished responding, they were asked a follow the given rout up to the next chosen road surface event. Each test participant was instructed to pay attention at all times to the road ahead, and to not let the questions/ study disturb their ordinary driving operation. If necessary the participants had the option to take a break between the judgements of steering wheel vibration signal ratings. Three preliminary test events, whose data were not analysed, were performed so as to familiarise the participant with the procedure before the actual eight events were rated. A GPS satellite navigation device was also used in order to guide the test participants through the designated route. The automobile speed associated with each stimulus was not provided, and no feedback was provided about the possible correctness of judgement. A complete field experiment lasted approximately 45 minutes min for each test participant. The field test protocol was reviewed and found to meet the University guidelines for good and ethical research practice.

6.5 – Field Study Results

The field study results for all six automobiles and for the 120 participants responses are presented in appendix 9, which include the subjective ratings for each of the eight road surface types. At first glance the results show similarities between the participant responses of the various road surface types, although the comparisons between each automobiles show less similarity, the results between the three segments show more of a trend among the two automobiles of each segment. Table 6.4 presents the mean activation ratings obtained across the whole group of 20 participants for the thirteen semantic vibrotactile dimensions for each of the six automobiles driven over eight road surface event types analysed in this field study.

For the purpose of clarity, simplicity and to better visualise the data, one of the descriptors from each of the 13 semantic dimensions was chosen as the main representative descriptor for each descriptive pair. The term semantic dimensions, is used to refer to the 13 descriptive pairs (vibrotactile adjectives) identified in chapter 5 of this thesis. So for example when looking at the mean activation ratings of the comfortable dimension for the Renault Clio, low bump road event result, the value of 2.0 suggests a 'moderately uncomfortable' perceived driver response.

Table 6.4 *Mean activation ratings obtained across the whole group of 20 participants for the driver emotional semantic scale to each of the eight road surface types driven by all six automobiles (n=120)*

Road Surface Type	Automobile	*Speed (km/h)*	*acceptable*	calm	*comfortable*	pleasant	*in-control*	safe	*powerful*	alarming	*bumpy*	sharp	*smooth*	regular	grippy
1 Low bump	Renault Clio	30	3.4	2.0	2.0	1.8	3.4	4.4	4.0	4.0	4.8	4.2	1.8	2.8	3.6
2 Broken road	Renault Clio	40	2.4	1.2	2.2	1.6	3.4	3.6	4.2	4.4	5.0	4.8	1.6	1.4	2.6
3 Country road	Renault Clio	40	3.4	2.6	2.6	2.2	3.0	3.6	3.4	3.4	4.2	4.2	2.4	3.0	3.0
4 Tarmac	Renault Clio	96	5.0	4.8	4.4	4.6	5.0	4.8	2.0	1.8	1.8	2.2	4.0	5.0	4.2
5 Rumble strips	Renault Clio	80	3.2	1.6	2.8	2.2	3.8	4.0	4.6	5.0	3.6	4.8	1.4	2.2	3.2
6 City Street	Renault Clio	40	4.4	4.6	4.4	3.6	4.8	4.4	1.8	1.6	3.0	2.0	3.6	4.2	4.2
7 Cobblestone	Renault Clio	30	2.4	1.6	2.2	1.4	3.4	3.8	4.2	3.4	4.6	4.2	1.2	1.6	4.2
8 Large bump	Renault Clio	20	4.4	3.8	3.4	2.2	4.0	4.6	3.2	3.2	4.4	3.0	2.6	2.8	4.6
1 Low bump	Volkswagen Polo	30	2.8	2.0	1.9	1.6	3.6	4.1	3.8	3.8	4.7	4.3	2.1	3.1	3.7
2 Broken road	Volkswagen Polo	40	1.8	1.1	1.8	1.4	3.3	3.1	4.3	4.3	4.8	4.9	1.4	1.3	2.8
3 Country road	Volkswagen Polo	40	3.1	3.0	2.4	2.3	3.5	3.6	3.1	3.0	3.8	3.5	2.5	2.4	3.6
4 Tarmac	Volkswagen Polo	96	4.9	4.6	4.5	4.4	5.0	4.8	1.6	1.6	1.9	1.9	4.6	4.9	4.6
5 Rumble strips	Volkswagen Polo	80	2.3	1.8	2.1	1.8	3.6	3.4	4.7	5.0	4.3	4.9	1.4	1.6	2.9
6 City Street	Volkswagen Polo	40	4.3	4.4	4.1	3.4	4.6	4.4	1.8	1.7	2.8	2.1	3.9	4.0	4.3
7 Cobblestone	Volkswagen Polo	30	1.9	1.5	1.9	1.5	3.6	3.3	4.3	3.2	4.3	4.6	1.3	1.3	3.4
8 Large bump	Volkswagen Polo	20	3.9	3.8	3.3	2.4	4.0	4.3	2.8	2.3	3.6	3.0	3.3	3.1	4.4
1 Low bump	BMW 1 Series	30	3.3	2.6	2.1	1.7	4.3	4.3	3.6	2.6	4.8	4.3	1.8	3.8	3.8
2 Broken road	BMW 1 Series	40	1.7	2.0	2.0	1.2	3.6	2.8	4.1	3.9	5.0	4.6	1.1	1.4	3.3
3 Country road	BMW 1 Series	40	4.1	3.1	3.3	3.0	4.7	4.1	3.0	2.9	3.5	2.9	2.6	2.4	4.1
4 Tarmac	BMW 1 Series	96	4.8	5.0	4.8	4.7	4.9	4.5	1.8	1.3	1.7	1.8	4.4	4.3	4.5
5 Rumble strips	BMW 1 Series	80	3.2	2.1	2.4	1.8	4.4	3.0	3.7	4.9	4.6	4.4	1.8	2.0	3.5
6 City Street	BMW 1 Series	40	4.8	4.6	4.4	4.3	4.9	4.7	2.0	1.4	1.8	2.2	4.3	4.5	4.5
7 Cobblestone	BMW 1 Series	30	3.5	2.0	2.5	1.8	3.9	3.8	4.0	3.4	4.8	4.2	1.8	1.6	2.9
8 Large bump	BMW 1 Series	20	4.0	3.2	2.8	2.4	4.6	4.7	2.6	2.6	4.3	3.2	2.6	3.2	4.1
1 Low bump	Volkswagen Passat	30	3.1	3.4	2.4	2.3	4.1	4.0	3.6	2.4	4.6	3.7	2.3	4.1	4.0
2 Broken road	Volkswagen Passat	40	1.7	1.6	2.0	1.4	3.6	2.9	4.1	3.7	5.0	4.6	1.7	1.3	3.6
3 Country road	Volkswagen Passat	40	3.3	3.1	3.1	2.7	4.3	3.4	2.7	2.4	3.6	3.1	2.6	2.3	3.9
4 Tarmac	Volkswagen Passat	96	4.7	4.7	4.9	4.1	4.6	4.4	1.9	1.6	1.4	1.7	5.0	4.4	4.6
5 Rumble strips	Volkswagen Passat	80	3.1	2.4	3.3	2.7	4.6	3.7	3.6	4.3	3.7	4.3	2.4	2.4	3.6
6 City Street	Volkswagen Passat	40	4.6	4.6	4.7	4.3	4.7	5.0	1.9	1.1	2.0	2.4	4.6	4.1	4.4
7 Cobblestone	Volkswagen Passat	30	3.0	2.3	2.9	2.1	3.4	4.0	3.7	3.4	4.9	4.6	1.6	2.1	2.7
8 Large bump	Volkswagen Passat	20	3.9	3.7	2.7	2.9	4.0	4.3	3.7	2.6	4.0	3.9	2.6	2.7	3.9
1 Low bump	Mercedes E Class	30	3.7	3.7	2.8	2.4	4.1	4.3	3.3	2.9	4.2	3.3	2.6	3.3	4.0
2 Broken road	Mercedes E Class	40	1.9	1.7	2.3	1.8	4.1	3.4	3.4	3.6	4.5	4.3	1.5	1.8	3.4
3 Country road	Mercedes E Class	40	3.6	2.9	3.2	3.3	4.3	4.1	2.6	2.6	3.8	3.4	2.6	2.5	3.6
4 Tarmac	Mercedes E Class	96	4.9	4.9	4.8	4.1	4.7	4.7	1.8	1.6	1.3	1.4	4.7	4.4	4.6
5 Rumble strips	Mercedes E Class	80	3.1	1.8	3.2	2.4	4.2	3.8	4.3	4.3	4.3	4.6	1.4	1.8	2.9
6 City Street	Mercedes E Class	40	4.4	4.2	4.5	4.0	4.8	4.5	2.0	1.7	2.6	1.9	4.3	3.8	4.6
7 Cobblestone	Mercedes E Class	30	2.6	1.8	2.6	2.0	4.3	4.1	3.9	3.4	4.7	4.5	1.4	2.1	2.8
8 Large bump	Mercedes E Class	20	4.1	3.4	3.4	2.8	4.5	4.6	3.7	2.7	3.6	3.2	2.9	3.3	4.1
1 Low bump	Audi A5	30	3.7	3.4	2.4	2.4	3.8	4.2	3.4	3.0	4.3	3.4	3.0	3.7	4.1
2 Broken road	Audi A5	40	1.8	1.7	2.7	2.0	4.0	3.7	3.2	3.4	4.6	4.4	1.6	1.9	3.9
3 Country road	Audi A5	40	2.9	3.1	3.3	3.2	4.1	4.0	2.3	2.3	3.6	3.4	2.4	2.7	3.6
4 Tarmac	Audi A5	96	4.9	4.9	4.8	4.1	4.6	4.6	1.9	1.6	1.1	1.6	4.8	4.4	4.7
5 Rumble strips	Audi A5	80	2.8	1.8	2.9	2.3	4.6	4.1	4.4	3.9	3.9	4.8	2.0	2.2	3.0
6 City Street	Audi A5	40	4.2	4.3	4.8	4.2	4.9	4.9	2.0	1.4	2.1	1.8	4.3	3.3	4.6
7 Cobblestone	Audi A5	30	2.4	1.8	3.1	2.3	4.1	4.1	4.0	3.4	4.7	4.6	1.7	2.2	3.1
8 Large bump	Audi A5	20	4.1	3.4	3.4	3.1	4.4	4.3	3.9	2.7	3.4	3.3	2.9	3.2	3.8

The change of the orientation for the descriptive pairs was carried out to help build the activation diagrams or the semantic space, which are used in this thesis to visualise the activation patters of the driver ratings of semantic descriptors. The semantic activation diagrams help the comparison between different road event types as well as between the automobiles tested. Also to better differentiate between the driver's responses from the different automobiles, a colour scheme was given to each of the six automobiles as shown in table 6.4. Using the mean participants ratings form table 6.4, the sematic diagrams illustrating the activation pattern for each of the thirteen descriptors were created as shown in figure 6.4.

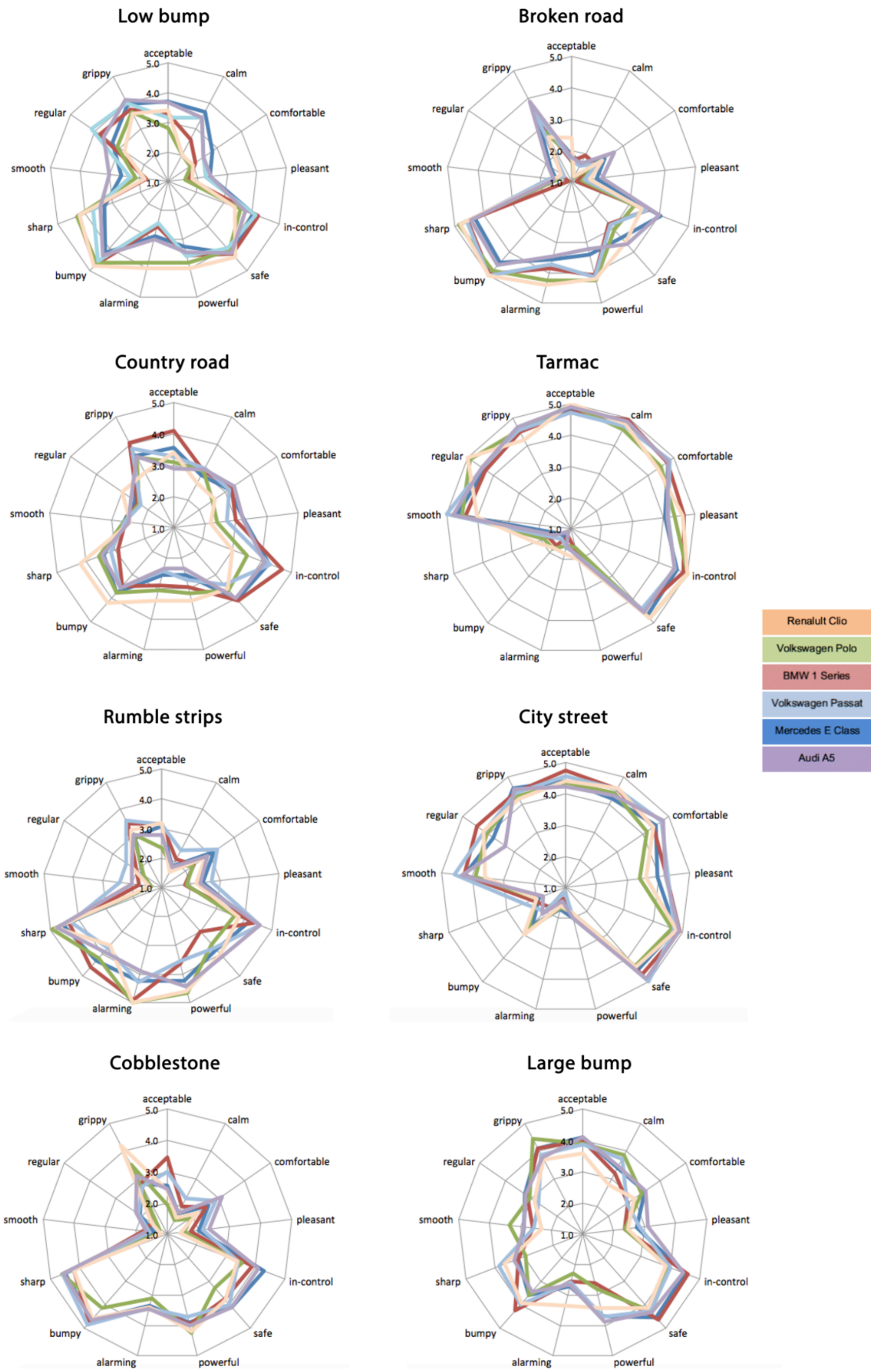


Figure 6.4 *The Semantic diagrams showing all six automobile's activation pattern over eight road surface types measured in the field study.*

At first glance the semantic diagrams show that the differential scale and the field study show that they effectively captured the activation patterns of the vibrotactile characteristics of each automobile. Trends can be seen between different patterns of each automobile for all roads, and when looking at fine details within the diagrams, the patters do match the expected emotional behaviour. For example, the alarming dimension for the low bump and the broken road is mostly activated 'alarming' for the segment-A automobiles whereas the other two segments show similarities between the two roads.

With further inspection additional patterns can be seen for the overall semantic diagrams, for example, the broken road and the cobblestone road, which are two of the road events with the most irregularities, show similar profiles among all cars. This is also especially the case for the road surface types with the least amount of irregularities or events, such as tarmac and city street, which show the most similarities amongst all six automobiles.

However there are also some patterns within the diagrams, which correlate less to what's expected, for example when looking at the red lines of the BMW 1 Series through all the roads, it is clear that there are unexpected peaks which don't follow the patterns of other automobiles, such as for the country road and the cobblestone road it was perceived the most acceptable out of all roads, and for the rumble strips and the large bump road it was perceived to be the bumpiest. This could just be due to the design of the driving dynamics of the BMW which makes it different at those specific events as the other five automobiles follow a closer trend to each other.

To get a better understanding of the six automobile's overall activation patterns, figure 6.5 was created to show the Semantic Space of each automobile and the mean driver responses throughout all of the road surface types assessed in this study. A clear trend can be seen for all six automobiles as they closely follow a similar pattern for the mean values of all road surface type ratings. Although a similar pattern of mismatch can also be seen for the BMW on this diagram, which for some of the semantic dimensions such as acceptable or in control, correlates closer to Segment C automobiles and for some dimensions such as bumpy, comfortable and safe, correlates closer to Segment A automobiles.

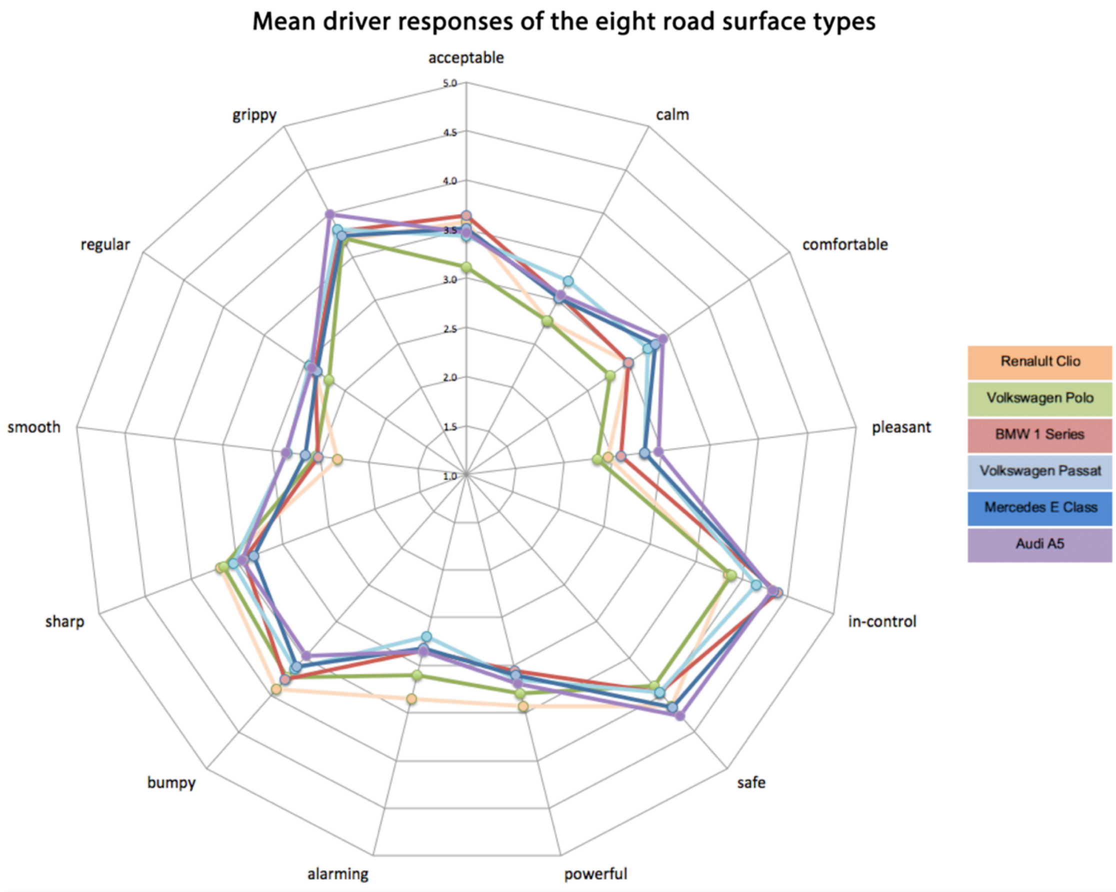


Figure 6.5 *The Semantic Space showing each automobiles activation pattern over all road surface types measured in the field study.*

6.6 – Principal Component Analysis

Although it's clear that the semantic differential technique is effective at gathering and presenting the participant responses of the vibrotactile descriptors of various automotive characteristics, it is also known in the scientific community for its effective use to identifying the dimensionality of the responses. So in addition to being able to create the semantic profiles of each of the stimuli assessed, the group of results can also be analysed in order to identify the main or the key dimensions which together account for the majority of the variance between the participants judgements of the automotive steering wheel character. Is essence further reducing the list of 13 descriptive pairs to the final definitive list, which together will aim to identify the majority of the variance of the vibration steering wheel feedback responses.

SPSS Statistics (IBM, 2013), a statistical analysis software was used in this study to carry out the principal component analysis on the participants ratings. An unrotated factor solution was applied to the components with the rotation method of the analysis set on direct oblimin criterion. This principal component analysis was carried out for extractions based on eigenvalues greater than 1.0, as research suggests (Kaiser, 1960) that only components with latent roots greater than one should be kept. Table 6.5 presents the correlation matrix table of all thirteen semantic dimensions.

Table 6.5 *Principal component analysis correlation matrix of all 13 semantic dimensions (n=120)*

Correlation Matrix

		acceptable	calm	comfortable	pleasant	incontrol	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Correlation	acceptable	1.000	.085	.455	.646	.005	.056	-.096	-.497	-.155	.142	-.175	.315	.209
	calm	.085	1.000	-.377	.307	.449	-.376	.615	.396	.245	.510	.332	-.240	.325
	comfortable	.455	-.377	1.000	.527	-.372	.399	-.206	-.528	-.342	-.381	-.052	.402	-.269
	pleasant	.646	.307	.527	1.000	.259	-.129	.121	-.544	-.179	.009	-.047	.591	.190
	incontrol	.005	.449	-.372	.259	1.000	-.654	.484	.082	.381	.445	.317	.064	.417
	safe	.056	-.376	.399	-.129	-.654	1.000	-.484	.028	.058	-.326	.181	-.225	-.712
	powerful	-.096	.615	-.206	.121	.484	-.484	1.000	.506	.232	.556	.415	-.275	.432
	alarming	-.497	.396	-.528	-.544	.082	.028	.506	1.000	.444	.318	.520	-.670	-.075
	bumpy	-.155	.245	-.342	-.179	.381	.058	.232	.444	1.000	.514	.688	-.487	.217
	sharp	.142	.510	-.381	.009	.445	-.326	.556	.318	.514	1.000	.441	-.456	.654
	smooth	-.175	.332	-.052	-.047	.317	.181	.415	.520	.688	.441	1.000	-.646	-.059
	regular	.315	-.240	.402	.591	.064	-.225	-.275	-.670	-.487	-.456	-.646	1.000	.065
	grippy	.209	.325	-.269	.190	.417	-.712	.432	-.075	.217	.654	-.059	.065	1.000

From the principal component analysis, four main components were extracted. Table 6.6 presents the total variance explained table which gives more detail on the dimensionality of the four semantic components identified by the analysis and the total eigenvalues for each component.

Table 6.6 *Total Variance Explained table of the four components extracted from the field study*

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.589	35.297	35.297	4.589	35.297	35.297
2	3.112	23.936	59.233	3.112	23.936	59.233
3	1.753	13.488	72.721	1.753	13.488	72.721
4	1.002	7.711	80.432	1.002	7.711	80.432
5	.869	6.688	87.120			
6	.620	4.769	91.888			
7	.343	2.642	94.530			
8	.281	2.161	96.691			
9	.185	1.422	98.112			
10	.111	.854	98.966			
11	.074	.568	99.534			
12	.037	.285	99.819			
13	.024	.181	100.000			

As can be seen in table 6.6, the first component extracted accounts for 35%, the second accounts for 24%, the third component accounts for 13% and the fourth component accounting for 8% of the variance, bringing the value of the total variance explained by the four components to a total of 80%. The four main components extracted from the principal component analysis of the field study results were ‘1 - sharp’, ‘2 - pleasant’, ‘3 - smooth’ and ‘4 - powerful’. Based on the word cloud created in Figure 5.4, the descriptors were rearranged to highlight the four dimensions identified by the principal component analysis as the main assessment criteria, capturing majority of the difference of opinion in automotive steering wheel vibration evaluations (Figure 6.6).

Figure 6.6 *Word cloud of the four components identified by the field study analysis.*

Table 6.7 shows the generated component matrix table of each component identified as well as the factor loadings for each descriptor, which together account for the majority of the variance between the participant judgements. Highlighted in green are the latent values of the main extracted components. Additional descriptors, which have considerably high loadings for each component identified are Component 1 sharp (powerful, alarming, bumpy), Component 2 pleasant (grippy, regular, acceptable), Component 3 smooth (comfortable, safe, acceptable), and Component 4 powerful (calm, alarming, pleasant), with the fourth component having very weak loadings. This spread of factor loading is consistent to Osgood's et al., (1957) findings which suggest that a descriptor can be identified as one component, but can still have a considerably great loading to another component.

Table 6.7 *Principal component analysis matrix table of each extracted component of the field study*

Component Matrix[a]

	Component			
	1	2	3	4
sharp	.773	.267	.184	-.381
powerful	.725	.292	.073	.396
alarming	.706	-.520	-.031	.276
bumpy	.666	-.197	.334	-.353
calm	.658	.347	.152	.378
comfortable	-.653	.172	.573	.118
smooth	.632	-.276	.609	.084
regular	-.626	.603	-.204	.146
incontrol	.588	.513	-.075	.097
pleasant	-.235	.779	.472	.230
safe	-.417	-.647	.561	-.070
grippy	.462	.647	-.218	-.422
acceptable	-.289	.592	.498	-.266

Extraction Method: Principal Component Analysis.
a. 4 components extracted.

As can be seen from table 6.6, the fourth component identified as the powerful dimension, has an eigenvalue of 1.002, which means it just about made it as a significant component due to our chosen software settings. Even without the powerful component, the first three main components account for 72.7% of the variance between the results, still covering the majority of the variance explained between the participant's judgements. As there is still a debate in the scientific community about the right eigenvalue choice for component extraction, ranging from 1 to 1.3.

Further analysis of the first two principal components extracted from the results was carried out to better understand the two main underlying dimensions. Figure 6.7 presents the factor loading plot for the first two components extracted, which is used to identify how the list of semantic descriptors of the scale correlate to the main components. The figure shows the sharp and the pleasant components represented by each axes and the correlation coefficient of each of the thirteen semantic descriptors.

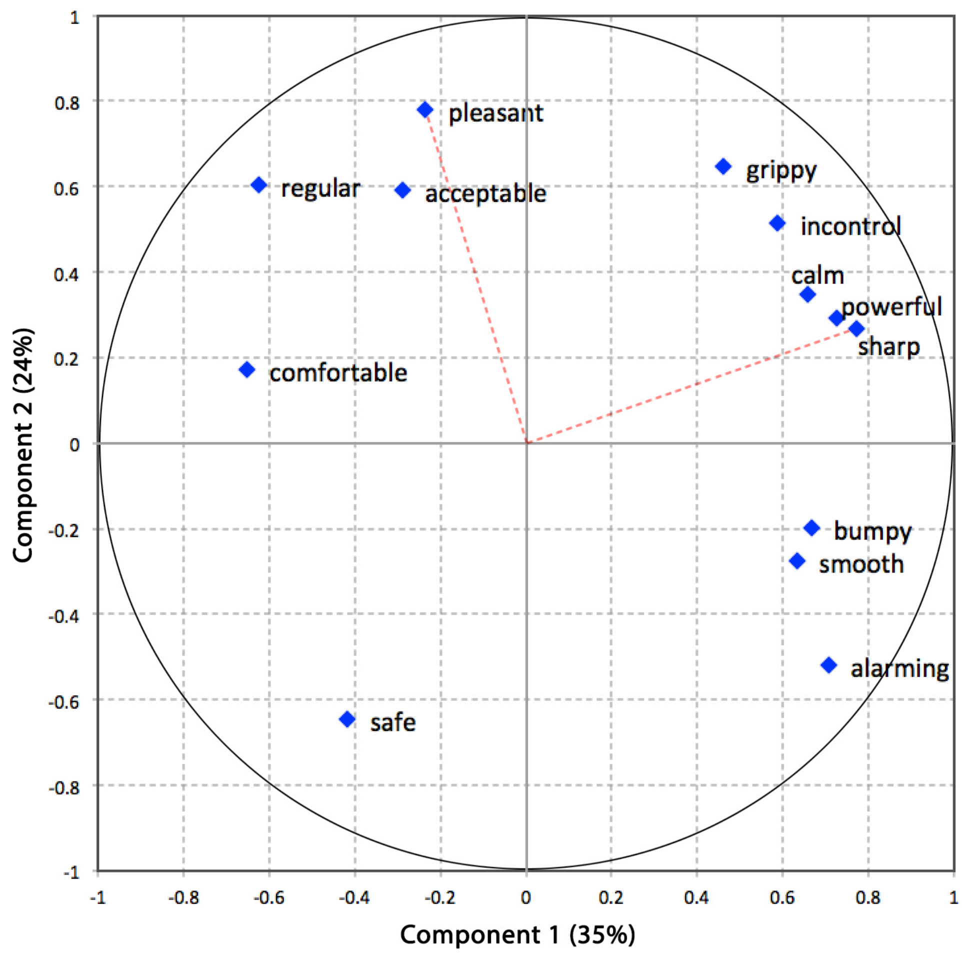


Figure 6.7 *Factor loading plot of the first two components (sharp - pleasant) identified by the field study analysis.*

The figure shows that the sharp dimension has the highest correlation with the first main principal component (sharp) while simultaneously the lowest correlation with the second principal component (pleasant). Likewise the pleasant descriptor has the highest correlation with the second principal component (pleasant) while simultaneously the lowest correlation with the first principal component (sharp). The chart therefore highlights that the sharp and the pleasant descriptors closely correlate with the first and the second principal components extracted.

In summary the principal component analysis conducted demonstrated that the characterisation of steering wheel vibration feedback descriptors could be reduced to four underlying dimensions identified as sharp, pleasant, smooth and powerful descriptors.

6.7 – Field Study Conclusion

The field-based study described in this chapter was carried out in order to measure the driver's emotional response to steering wheel vibration of six automobiles in actual road driving scenarios to assess the thirteen semantic descriptors. The main aim was to discover if these thirteen semantic descriptors are reliable when measuring the vibratory feedback and to identify which of the dimensions account for the majority of the variance between the participants judgements which will in turn, group the main language defining the drivers emotional semantics of steering wheel vibration feedback. This study involved the assessment of the Driver Emotional Semantic scale built in Chapter 5 of this thesis, which included the thirteen descriptive pairs identified by drivers as vibrotactile associated descriptors. The scale was used to rate the participants judgements of a group of eight road surface types. Six automobiles from three automotive segments were tested in this study, with twenty participants assessing each automobile, and a total of 120 individual test drives carried out.

The filed study results were used to create the semantic activation pattern for each of the eight road surface types, showing the level of activation for all thirteen descriptive pairs of the semantic scale, in turn capturing the visual representation of each automobiles vibration feedback characteristics. This showed that the semantic differential scale could accurately capture the driver's subjective response to a wide variety of dimensions when assessing automotive steering wheel vibration feedback. Further analysis of the field study results using a principal component analysis, made it possible to identify the key dimensionality of the descriptive pairs assessed from the driver's judgements. This highlighted the main descriptive categories (components), which have the largest possible variance to the rest of the descriptors.

Results suggest that the **four descriptors** identified from this field study, (namely: **sharp, pleasant, smooth and powerful**) account for over 80% of the total variance observed between the participants judgements of the eight steering wheel vibration feedback. Which leads to the conclusion that in order to measure the automotive steering wheel vibration feedback, this group of four semantic dimensions could be suitable to capture up to 80% of the difference between the possible participant judgements in a field study scenario.

Based on the field study results, it is evident that that the Driver Emotional Semantic scale developed in this work could be used to accurately capture most of the variability and the activation patterns of the driver emotional responses to steering wheel vibrations. The results also show that the vibration feedback characteristics measured using the descriptive pairs makes it possible to differentiate between the automotive types as trends are visible throughout the automotive segments and the different road surface types making for easier comparison between the measures.

Also when considering the descriptive pairs identified by the Principal Component Analysis as the key components accounting for the majority of the possible variability of participant responses, it is clear that the main three components identified, closely relate to the research findings of Osgood et al., (1957) which consistently highlighted the basic recurring dimensions that people use to assess different concepts of evaluation, potency, and activity. The evaluative component being associated to the pleasant - annoying dimension of the scale, the potency component associated to the smooth - rough dimension of the scale and the activity component associated to the sharp - dull dimensions of the semantic scale. This suggests that the methodology carried out to answer the research question of this study and the Driver Emotional Semantic scale created with the vocabulary defined would be consistently reliable to measure human emotional responses to automotive steering wheel vibration when used in real road scenario.

Chapter 7 – Exp.5 – Assessing the reliability of the driver emotional semantic scale in laboratory based setting

7.1 – Introduction

This chapter introduces the final experimental test procedure, which involved a laboratory study in order to measure the reliability of the Driver Emotional Semantic scale in a laboratory based setting using the same thirteen verbal descriptors obtained from the field study (Chapter 5) and to compare the results obtained with the field test scenario results (Chapter 6). The steering wheel vibration acceleration data used in this experiment were recorded from three of the automobiles and from five real road surface types, which were selected from the previous field study experiment described in Chapter 6 (Exp.4).

Three automobiles were selected in order to have one automobile class from each of the three automotive segments defined in the previous field test experiment (Chapter 6). The main aims of this chapter were to compare the driver's judgements of steering wheel vibration feedback when perceived in a laboratory test with their judgements from real driving scenarios in field study, and to verify if the same dimensionality (i.e. 1 - sharp', '2 - pleasant', '3 - smooth' and '4 - powerful') could be repeatable between the two experimental methods (field study and laboratory test).

7.2 – Experiment Test Stimuli

The vibration test stimuli used for this laboratory experiment included a total of fifteen steering wheel acceleration signals, which were recorded directly from the steering wheel of three automobiles, while driving over five different road surface types each. In order to allow all participants of this study to subjectively rate each of the chosen stimuli twice for better accuracy and a repetition of the judgements, the number of roads and the number of automobiles was reduced to assess the main five road surface types driven over three cars. This selection was also done to limit the total experiment running time to under one hour and fifteen minutes, in order to allow participants to finish within a reasonable amount of time, while avoiding fatiguing the participant and impairing their judgements (Coolican, 1999).

The results from the field study ratings of all eight roads as well as mock tests and road vibration recording data, was used in order to select which of the road surface types to eliminate from the eight field study road surface types, this involved removing three of the surface types, which were rated as similar. The first road surface type removed, was the City street road, which when looking at figure 6.4, clearly stands out as a similar profile to the Tarmac road, as they are both the two roads to feature the least surface irregularities. The second road to be removed from the list of road surface types was the Cobblestone road, which was due to participant's response in the mock test and the field study, as many people described them as feeling very similar when compared to the Rumble strips road surface type. Similarities can also be seen from the semantic profile diagrams (figure 6.4) between the two roads for all semantic dimensions except for the alarming-unalarming descriptive pair. Finally the last road surface profile to be removed was the Large bump road, this road was also described as very similar to the Low bump road, and the semantic profile diagrams also show this similarity between the judgements.

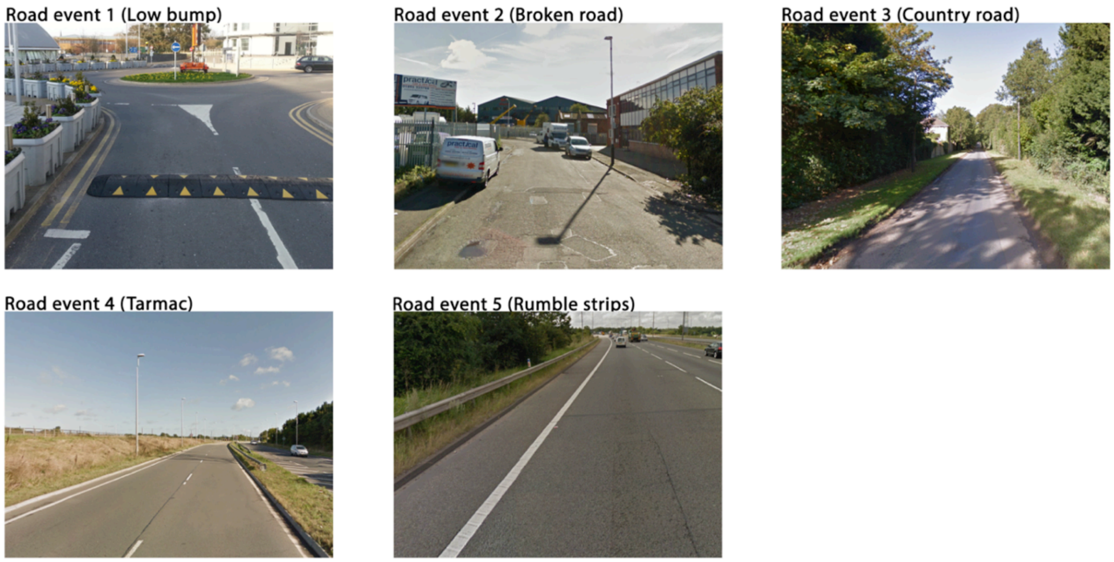


Figure 7.1 *Drivers view of the five road surface events tested in this laboratory study (also oncluded in the field study).*

Figure 7.1 presents the drivers view of the chosen five road event types recorded with each automobile, which for consistency, included the same road types (Figure 6.2) as in the previous field study (1-Low bump, 2-Broken road, 3-Country road, 4-Tarmac, 5-Rumble strips,). Table 7.1 shows the details of the five reads tested, including the location and the automobile speed.

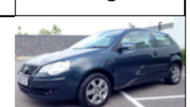
Table 7.1 *Laboratory study road surface types recorded with each of the three chosen automobiles.*

Road Surface Type	***Road Location***	***Event Type***	***Speed (km/h)***	**Event Duration**
1 - Low Bump	Brunel University - South Loop	Transient	30	10s – 20s
2 - Broken Road	Arundel Road	Random	40	30s – 1m
3 - Country Road	Seven Hills Road	Random	40	30s – 1m
4 - Tarmac	A412 Denham Road - M40	Random	96	30s – 1m
5 - Rumble Strips	Denham Roundabout - M40	Transient	80	30s – 1m

For each of the five road surface types tested, a two-minute recording of the steering wheel acceleration had been measured by means of an accelerometer which was rigidly clamped to the surface of the steering wheel at the 60° position (two o'clock position) with respect to top centre which is the most common grip position adopted by nonprofessional driver's. This was done consistently for all three automobiles of the three segments. The accelerometer had been mounted so as to measure the acceleration in the direction, which was tangential to the steering wheel rotation. For all roads and automobiles tested, the accelerometer type and the mounting clamp used were appropriate for measuring the frequency range from 0 to 300 Hz. A total of fifteen steering wheel time histories were recorded from all of the three chosen automobiles, which were driven in a straight line over the five road event types, at a speed that was consistent with the surface type (Department of Transport, 2006). During the data recording it was a key consideration to drive along the same exact path/patch of each of the chosen road surface types, consistently with all vehicles driving at the same speed. For all driving conditions, a 7-second segment was taken so as to remain within human short term memory (Baddeley, 1997).

The three European automobiles used to record the steering wheel acceleration signals for this study where selected from different automotive segments (Seg A, Seg B, and Seg C), and included the Mercedes-Benz E-Class, a Volkswagen Passat, and a Volkswagen Polo. Table 7.2 presents each of the three automobiles tested and additional information about the model type details.

Table 7.2 *Automotive properties of three of the automobiles used to record the test stimuli for the laboratory study.*

Automotive Class	Automobile Model & Make	Model Year	Automobile Type	Automobile Weight	Image
Segment A	Volkswagen Polo 1.9	2009	Small Hatchback	1650 kg	
Segment B	Volkswagen Passat 1.9	2009	Small Saloon	2060 kg	
Segment C	Mercedes E Class 2.2	2005	Medium Saloon	2140 kg	

Since none of the steering wheel acceleration time histories recorded, contained significant vibrational energy at frequencies greater than 120 Hz, the decision was taken to apply a bandpass digital Butterworth filter to limit the vibrational energy to the frequency range from 3 Hz to 120 Hz, the lower cut-off value of 3 Hz having been chosen in recognition of the frequency response limitations of the electrodynamic shaker unit of the laboratory test bench.

To ensure a highly accurate reproduction of the actuated acceleration signals from the laboratory test bench, an evaluation of all fifteen road test signals was carried out using the LMS software. The accuracy of the acceleration signal was measured by identifying the maximum r.m.s. error between the target signal (recorded steering wheel vibration) and the reproduced steering wheel vibration as measured from the laboratory test bench. All of the target signal acceleration r.m.s. values, were extracted from the fifteen recorded signals, whereas the reproduced acceleration r.m.s. values were measured directly from the steering wheel vibrations of the test bench.

Digital filters, which are used to manipulate an oscillatory signal to a chosen desired state, processing an input source to generate the desired output, were applied using signal processing to the steering wheel vibration recordings. Digital filters can offer a much higher level of accuracy in design application with higher precision and better conditioning towards the desired type of stimuli. Compensation filters were created for each of the road acceleration signals, in order to compensate for the effect of change in the frequency response caused by the test bench shaker and other components. The maximum percentage of error between the respective power spectral densities of the target r.m.s. values and the reproduced r.m.s values was calculated after each compensation filter was applied. Three participants took part in a mock test to evaluate the filters in order to further consider the difference in of body weight loadings on the steering wheel. After all the compensation filters were applied to each of the fifteen vibration acceleration stimuli, the maximum percentage of error between he target r.m.s. values and the reproduced r.m.s. values was found to be below 10%, which is less than the proposed just-noticeable-difference value for human perception of hand-arm vibration of 15 to 18% (Morioka, 1999).

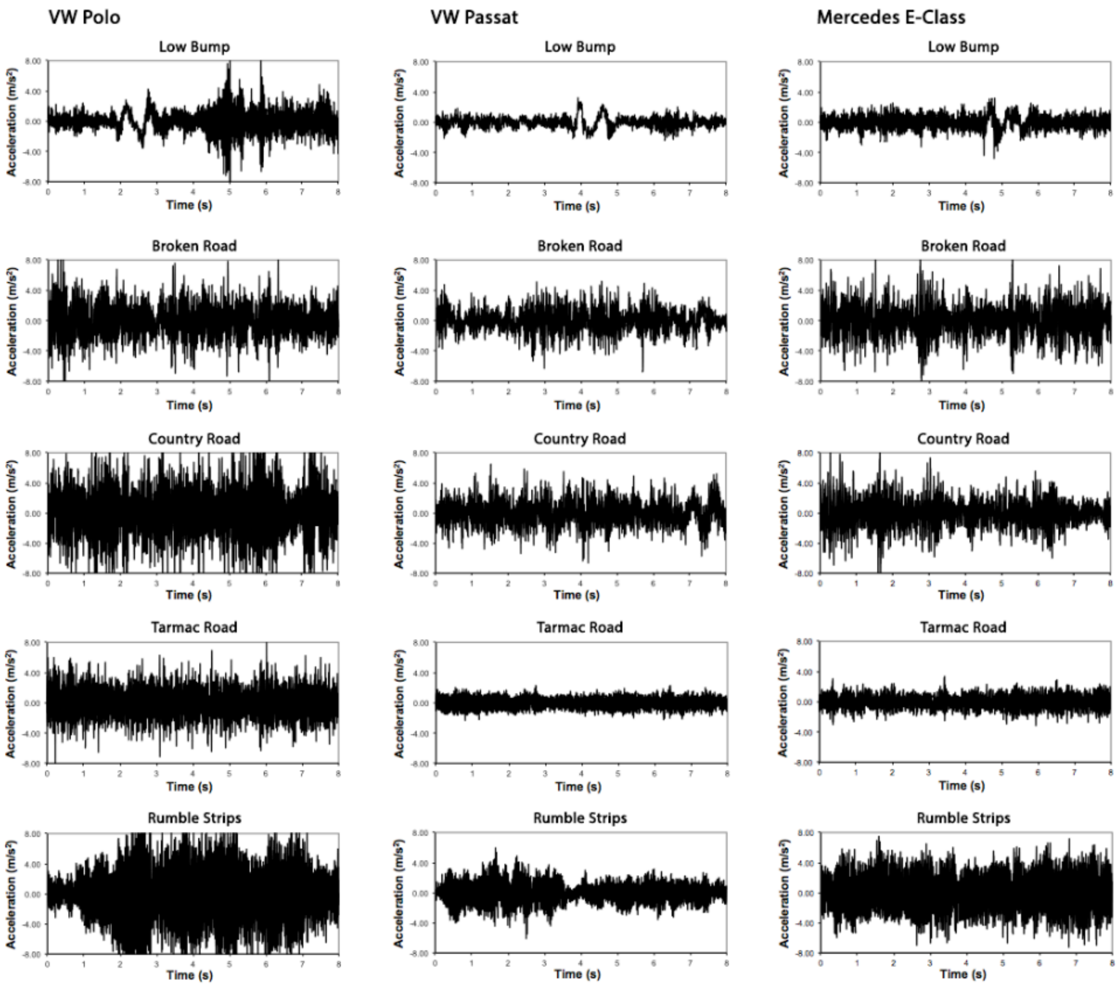


***Figure 7.2** The fifteen steering wheel acceleration time history segments for three automobiles, used in the laboratory study.*

Further signal analysis was carried out using the LMS CADA-X software to examine the road acceleration signal properties. Figure 7.2 presents the resulting time history segments form the fifteen vibration signals tested in this laboratory study.

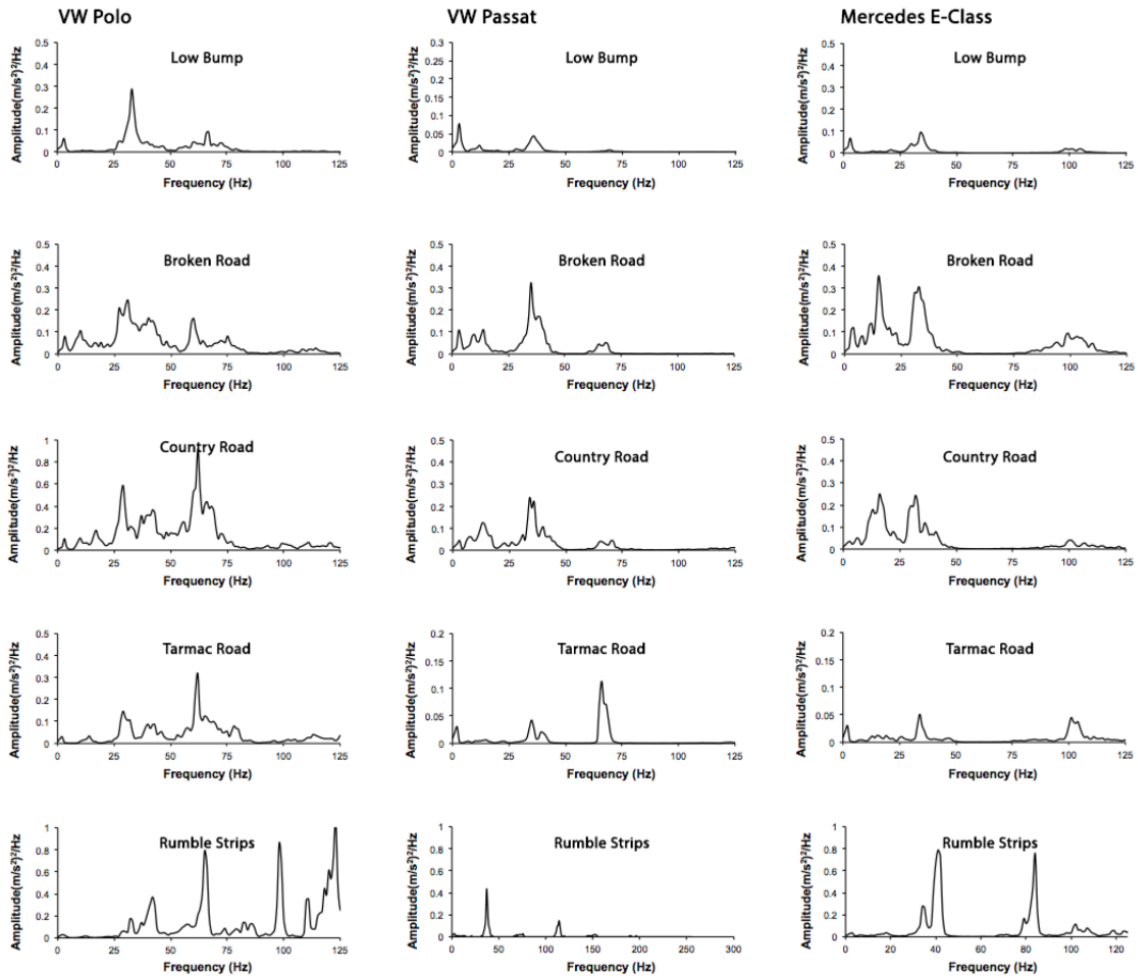


Figure 7.3 *The Power Spectral Densities (PSD) calculated from the fifteen steering wheel acceleration time history segments.*

Figure 7.3 presents the respective power spectral densities of the 15 acceleration signals, which shows that a significant amount of vibrational energy is present in the frequency range between 10 and 60 Hz, and that vibrational energy is much lower outside this range.

The global statistical properties calculated for the complete list of original acceleration recording over each road surface and automotive segment is presented in Table 7.3. The signal global statistical properties, show that the steering wheel vibration accelerations achieved root mean square values are highest for the Volkswagen Polo, which is the lowest class of category out of the three segments.

Table 7.3 *Global statistical properties of the steering wheel acceleration time histories for the fifteen road driving conditions which were used as test stimuli in the experiments.*

	Road Surface Type	*Speed (km/h)*	*r.m.s vibration level (m/s²)*	*Kurtosis*	*Skewness*	Crest factor
VW Polo	1 - Low Bump	30	1.48	3.82	0.02	7.60
	2 - Broken Road	40	2.22	1.07	0.03	5.30
	3 - Country Road	40	3.43	0.53	-0.02	4.56
	4 - Tarmac	96	2.03	0.25	0.04	4.30
	5 - Rumble Strips	60	3.43	0.40	-0.12	4.24
VW Passat	1 - Low Bump	30	0.74	1.13	0.19	3.86
	2 - Broken Road	40	1.54	0.60	-0.09	5.28
	3 - Country Road	40	1.76	0.39	0.04	5.35
	4 - Tarmac	96	0.80	-0.25	-0.02	3.69
	5 - Rumble Strips	60	1.39	0.82	-0.06	5.30
MB E-Class	1 - Low Bump	30	0.93	0.68	-0.17	4.96
	2 - Broken Road	40	2.19	1.57	0.16	6.38
	3 - Country Road	40	1.91	1.53	-0.04	5.37
	4 - Tarmac	96	1.02	0.19	-0.01	4.69
	5 - Rumble Strips	60	2.73	-0.11	0.10	4.10

In order to carry out this laboratory study, the same exact experimental test bench (as described in section 4.3.2 of this thesis), with the same geometric dimensions was used as previously shown in figure 4.10. Since the last laboratory study of chapter 4, no modifications or alterations were carried out on any of the vibration test rig components.

7.3 – Laboratory Test Participants

A total of 25 university students and staff took part in this laboratory experiment. A consent form and a short questionnaire was given out to each participant prior to testing (Appendix 10), which was used to gather information, regarding their anthropometry and build, gender, age, height, weight and previous driving experience. The participants were also requested to state whether they had any physical or mental condition that might affect the perception or the emotional response to hand-arm vibration, and whether he or she had smoked or ingested coffee within the 2 hours previous to arriving in the laboratory.

Table 7.4 *Physical characteristics of the group of test participants involved in the laboratory experiments (n=25)*

Characteristics		Mean	Standard Deviation	Minimum	Maximum
Age	**(years)**	29.5	9.3	19.0	56.0
Height	**(m)**	1.8	0.1	1.6	2.0
Mass	**(kg)**	79.5	12.9	55.0	118.0

Table 7.4 presents a basic summary of the physical characteristics of the group of test participants. The group consisted of 17 males and 8 females. The mean values and the standard deviation of the height and weight of the test participants presented in Table 7.4 were along the 50 percentile values for the average U.K. driving population (Pheasant and Haslegrave, 2005). None of the test participant declared a physical or a cognitive condition, which might affect their perception of hand-arm vibration. All subjects declared themselves to be in good physical and mental health and none declared having smoked or ingested coffee prior to arriving in the laboratory. All had more than two years of driving experience.

7.4 – Laboratory Test Protocol

As the aim of this laboratory experiment was to identify the key dimensionality between the driver's judgements of perceived vibrations in a simulated driving scenario, an evaluation of the same semantic scale with all thirteen descriptive pairs was carried out. This was carried out in order to allow for a comparison of the key dimensions identified by the principal component analysis for the driver judgements of the field study results and the judgements of the laboratory setting, in turn comparing the participants judgements of the vibration feedback with and without the additional visual and auditory multisensory feedback.

The same driver vibration semantic rating scale (as developed in chapter 5) was used in this laboratory study to measure the test participant's emotional response of the steering wheel vibration feedback. Although the same thirteen descriptive pairs, with the same five point Likert scale was used by each participant to assess all road vibration signals, the order of the descriptors was presented again in a random order to minimize any possible bias resulting from learning or fatigue effects. During the rating process of the vibration test bench feedback, roughly when the participants reached half way down the rating scale, the same acceleration stimuli were repeated in order to refresh their memory of the same stimuli being rated. If they found necessary, participants also had the option to take a break between the judgements of the steering wheel vibration signals.

Semantic Differential Scale

	Extremely	Moderately	Neither	Moderately	Extremely	
aggressive	○	○	○	○	○	calm
alarming	○	○	○	○	○	unalarming
comfortable	○	○	○	○	○	uncomfortable
out-of-control	○	○	○	○	○	in-control
pleasant	○	○	○	○	○	annoying
powerful	○	○	○	○	○	weak
safe	○	○	○	○	○	not-safe
acceptable	○	○	○	○	○	unacceptable
bumpy	○	○	○	○	○	even
regular	○	○	○	○	○	irregular
rough	○	○	○	○	○	smooth
sharp	○	○	○	○	○	dull
slippery	○	○	○	○	○	grippy

Figure 7.4 *The Driver Emotional Semantic scale used to measure participants responses in laboratory test bench.*

Before commencing testing each subject was required to remove any heavy clothes and accessories, such as coats, watches, jewellery etc. They were then asked to adjust the seat position and backrest angle so as to simulate their preferred driving posture as realistically as possible. Since grip type and grip strength (Reynolds and Keith, 1977) are known to effect the transmission of vibration to the hand-arm system, the subjects were asked to maintain a constant palm grip on the steering wheel using both hands. The subjects were also asked to wear ear protectors so as to avoid auditory cues. Room temperature was maintained within the range from 20°C to 25°C so as to avoid significant environmental effects on the skin sensitivity (ISO 13091-1, 2001).

The semantic differential scale (Figure 7.4) was positioned on a stand at about 1m ahead, such that the centre of the board was approximately at eye height of the test participant. Each of the fifteen stimuli was repeated two times, to all of the 25 participants, gathering a total of 30 road vibration stimuli judgements by each test participant. The order of each repetition of road vibration stimuli, as well as the order of each automobile presented was randomised to avoid any possible bias resulting from learning or fatigue effects that could impairing the participant's judgements. During each test a series of 7-second steering wheel acceleration stimuli was presented to the participant, using a minimum of 60-second gap between each stimulus, during which each participant was asked to rate their emotional state of the perceived vibration felt through the steering wheel using the semantic differential scale. Providing participants 60 seconds (although this time could be overridden if necessary) in which to consider the stimulus, self-reflect on the emotional state produced, and rate their perceptions, one descriptive pair at a time. In addition, a total elapsed time of 60 seconds per stimuli judgement also was shown to be appropriate, due to allowing the participant to perform all relevant subjective ratings within the confines of human short-term memory (Baddeley, 1997).

Mock runs of the test protocol were also carried out in order to measure average test response time using the 13 descriptors and in order to regulate the total estimated time to complete each test. The time it took each participant to respond using all the 13 verbal descriptors can significantly change depending on the age or experience of the participant, as some tests especially with the elderly age group resulted in test runs lasting significantly longer than the average. Three preliminary road test stimuli, whose data were not analysed, were performed so as to familiarise the participant with the rating procedure. The automobile speed associated with each stimulus was not provided, and no feedback was provided about the possible correctness of judgement. A complete experiment lasted approximately 55 minutes min for each test participant. The facility and protocol were reviewed and found to meet University guidelines for good research practice.

7.5 – Laboratory Test Results

The laboratory study results for all 25 participants tested are shown in appendix 11 which include the responses to all 30 steering wheel vibration feedback (2 x repetitions of 15 signals), for every one of the descriptive pairs of the semantic differential scale. At first glance it is clear that the data covered a wide spectrum of values, with less visible similarities between the judgements as compared to the field study results. For consistency and visualisation, the same choice of main defining descriptor and the orientation of the descriptive pairs was applied to the laboratory results as defined in the previous field study (Section 6.5). To better explore the results, the mean activation ratings obtained across the whole group of 25 participants and across the repeated judgements were calculated. Table 7.5 presents the mean activation ratings of all emotional descriptive pairs for each of the fifteen road vibration stimuli, including the respective r.m.s. acceleration value of each steering wheel vibration stimuli.

Table 7.5 *Mean activation ratings obtained across the repetition of judgements and across the whole group of participants involved in the laboratory experiments (n=25)*

Automobile	Road Surface Type	*Speed (km/h)*	*r.m.s. (m/s^2)*	*acceptable*	calm	*comfortable*	pleasant	*in-control*	safe	*powerful*	alarming	*bumpy*	sharp	*smooth*	regular	grippy
Volkswagen Polo	1 Low bump	30	1.5	2.9	2.4	2.6	2.3	3.4	3.2	3.5	3.5	4.2	4.0	2.1	2.3	3.3
	2 Broken road	40	2.2	3.6	2.5	3.0	2.9	3.8	3.7	3.3	3.3	3.9	3.4	2.2	2.9	3.6
	3 Country road	40	3.4	2.5	1.8	2.3	2.0	3.0	3.3	4.0	3.9	4.2	3.8	1.8	2.2	3.0
	4 Tarmac	96	2.0	3.5	2.9	3.2	2.7	3.8	3.9	3.3	3.1	3.4	3.3	2.3	3.1	3.7
	5 Rumble strips	80	3.4	2.2	1.6	1.9	2.0	2.8	2.9	4.3	4.3	4.1	4.2	1.6	2.5	2.6
Volkswagen Passat	1 Low bump	30	0.7	4.7	4.8	4.7	4.3	4.7	4.6	1.8	1.3	1.8	1.5	4.5	4.5	4.1
	2 Broken road	40	1.5	3.9	3.4	3.6	3.0	4.1	3.9	2.8	2.4	3.1	2.9	2.8	3.4	3.7
	3 Country road	40	1.8	3.6	2.9	3.3	2.9	3.9	4.1	3.0	2.9	3.4	2.8	2.8	3.0	3.7
	4 Tarmac	96	0.8	4.6	4.7	4.5	4.1	4.6	4.6	1.8	1.6	1.7	1.6	4.3	4.4	4.3
	5 Rumble strips	80	1.4	3.7	3.7	3.6	3.2	4.1	3.8	2.7	2.6	3.2	3.1	3.1	3.3	3.5
Mercedes E Class	1 Low bump	30	0.9	4.3	4.0	4.0	3.7	4.3	4.4	2.1	2.1	2.4	2.3	3.6	3.9	3.8
	2 Broken road	40	2.2	2.7	2.2	2.6	2.4	3.1	3.3	3.5	3.8	4.1	3.8	2.1	2.1	3.1
	3 Country road	40	1.9	3.5	2.7	3.1	2.9	3.7	3.8	3.3	3.0	3.5	3.2	2.4	3.1	3.4
	4 Tarmac	96	1.0	4.4	4.4	4.2	3.9	4.4	4.5	2.1	1.9	2.0	2.1	4.0	4.2	4.2
	5 Rumble strips	80	2.7	3.6	2.4	3.1	2.9	3.8	3.9	3.4	3.2	3.3	3.2	2.6	3.3	3.7

Although responses from all participants show a low similarity between the judgements, some similarities can be seen among the results for the low intensity (r.m.s.) road acceleration data such as for the tarmac road or low bump of the Mercedes E-Class and the Volkswagen Passat automobiles. The similarities observed could be due to the similar characteristics of the time histories (Figure 7.2) and power spectral densities (Figure 7.3) between these road stimuli. Figure 7.5 presents the semantic diagrams of the mean activation rating of each automobile vibration profile. At first glance the activation profiles of the Mercedes E-Class and the Volkswagen Passat show the closest profiles, with similar activation patterns for most roads when comparing between all three automobiles.

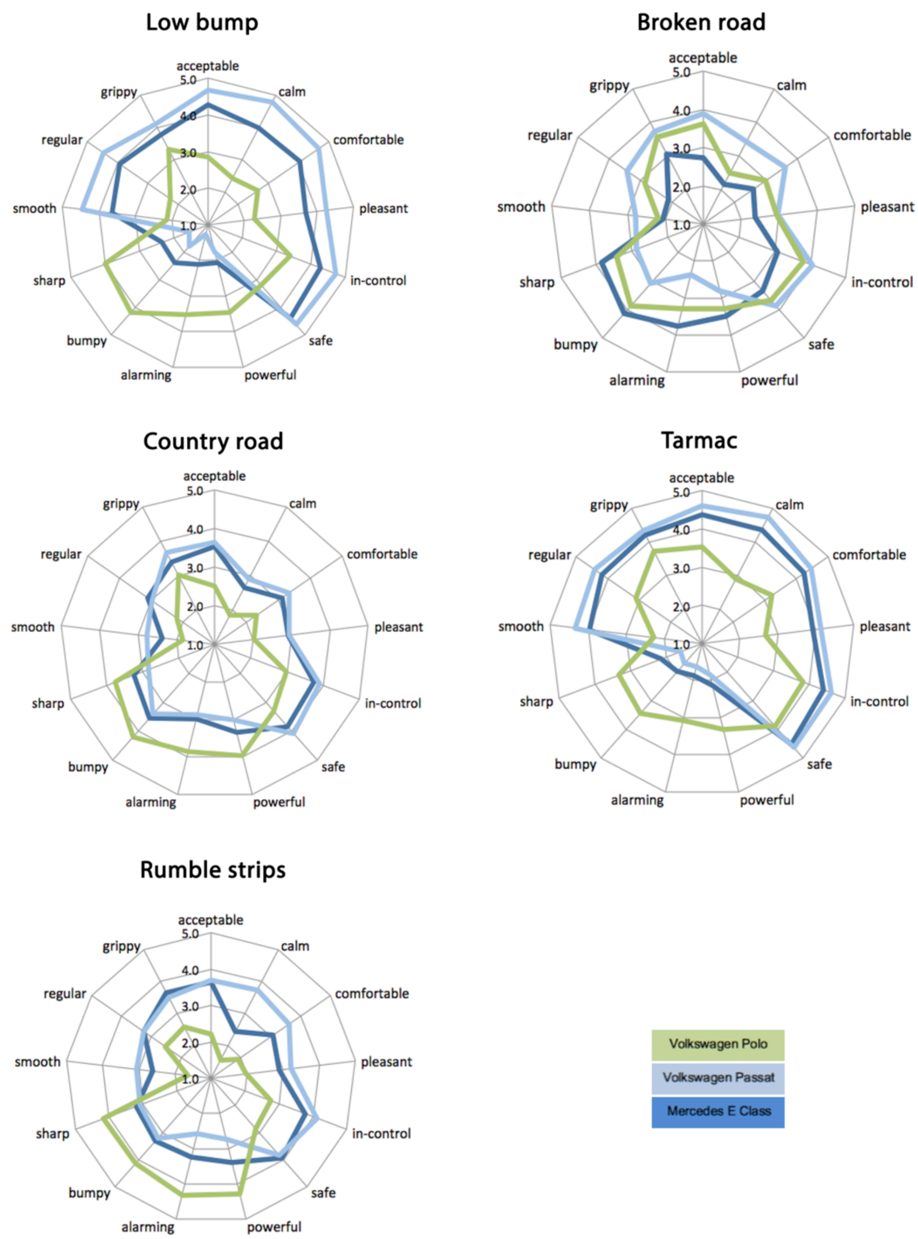


Figure 7.5 *The Semantic diagrams showing all three automobile's activation pattern over five road surface types measured in the laboratory test.*

The VW Polo shows the most distinct activation profiles amongst all automobiles, this is shown throughout the five road surface types. Although the VW Polo also shows a distinct pattern in the field study results, the variations amongst the results of the laboratory study show extreme differences of activation patterns when compared to the other two automobiles. With further examination of the results and while considering the global signal statistics (Table 7.3) of all signals used, it can be concluded that the reason for this large distinction between the Volkswagen Polo and the other two automobiles is due to the extremely high intensity of the polo's acceleration signals recorded. Whereas the Volkswagen Passat and the Mercedes E-Class, show a greater similarity amongst their global statistics values, which resulted in them having a similar activation profile as when compared to the activation profile of the Volkswagen Polo. The comparison between the three automobile results shows that the vibration r.m.s intensity is the key dominating factor when assessing the driver subjective response of the vibrotactile vocabulary, and the difference of intensity between the automobiles correlated with the difference in the participants subjective response. This also suggests that the laboratory test bench simulation focuses more on the intensity factor of the stimuli of the driving experience. Figure 7.6 presents the overall mean activation patterns of each automobile measured across all road surface type signals. The semantic space of each automobile's activation pattern shows three very different profiles for each automobile, and the generated pattern that they follow, tends to defy what's to be expected, as the order of activation of profile intensity does not correlate to the representative global statistical properties and the order of group segmentation (the VW Passat at one end of the scale, the MB E-Class in the middle and the VW Polo at the other end, as opposed to E-Class, Passat and Polo).

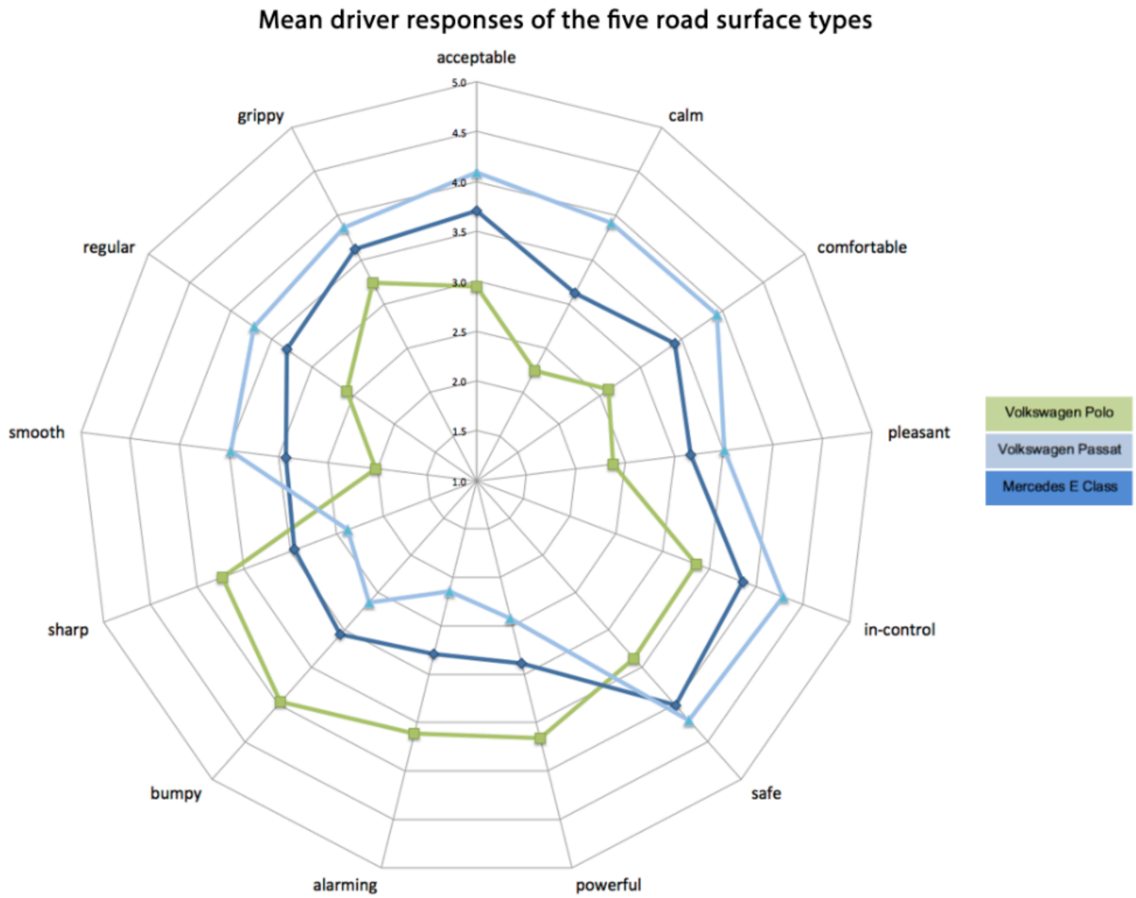


Figure 7.6 *The Semantic Space showing each automobiles activation pattern over all road surface types measured in the laboratory test.*

7.6 – Principal Component Analysis

The SPSS statistical software package (IBM, 2013) was used to carry out a principal component analysis on the laboratory results gathered from the participant's judgements. The principal component analysis was carried out in order to identify the key semantic descriptors that together account for as much of the variability in the data set as possible. This will in turn define the dimensionality of the driver's vocabulary of steering wheel vibration feedback as perceived from a laboratory test bench scenario. The same settings that were used to define the properties for the field study principal component analysis (Chapter 6) were used to set up the principal component analysis for the laboratory results. As research suggests (Kaiser, 1960) that only components with latent roots greater than one should be kept, extractions based on eigenvalues greater than 1.0 were identified as principal components. Table 7.6 presents the correlation matrix table of all thirteen semantic dimensions extracted from the laboratory study results.

Table 7.6 *Principal component analysis correlation matrix of all 13 semantic dimensions (n=25)*

Correlation Matrix

		acceptable	calm	comfortable	pleasant	incontrol	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Correlation	acceptable	1.000	-.637	.721	.693	-.668	.692	-.576	-.651	-.612	-.557	-.619	.674	-.549
	calm	-.637	1.000	-.764	-.657	.604	-.527	.725	.813	.741	.685	.743	-.623	.461
	comfortable	.721	-.764	1.000	.721	-.664	.625	-.669	-.748	-.653	-.612	-.717	.633	-.490
	pleasant	.693	-.657	.721	1.000	-.588	.588	-.539	-.662	-.613	-.549	-.634	.615	-.438
	incontrol	-.668	.604	-.664	-.588	1.000	-.753	.542	.612	.532	.491	.530	-.557	.610
	safe	.692	-.527	.625	.588	-.753	1.000	-.498	-.542	-.496	-.430	-.493	.519	-.543
	powerful	-.576	.725	-.669	-.539	.542	-.498	1.000	.707	.648	.621	.682	-.559	.379
	alarming	-.651	.813	-.748	-.662	.612	-.542	.707	1.000	.671	.647	.690	-.613	.473
	bumpy	-.612	.741	-.653	-.613	.532	-.496	.648	.671	1.000	.716	.760	-.725	.442
	sharp	-.557	.685	-.612	-.549	.491	-.430	.621	.647	.716	1.000	.756	-.647	.438
	smooth	-.619	.743	-.717	-.634	.530	-.493	.682	.690	.760	.756	1.000	-.655	.421
	regular	.674	-.623	.633	.615	-.557	.519	-.559	-.613	-.725	-.647	-.655	1.000	-.474
	grippy	-.549	.461	-.490	-.438	.610	-.543	.379	.473	.442	.438	.421	-.474	1.000

From the principal component analysis, only two main components were extracted, table 7.7 presents the total variance explained table, which gives more detail on the dimensionality of the two semantic components identified by the analysis and the percentage of the accounted variance of each component.

Table 7.7 *Total Variance Explained table of the two components extracted from the laboratory study*

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.940	63.860	63.860	8.940	63.860	63.860
2	1.174	8.389	72.249	1.174	8.389	72.249
3	.614	4.384	76.633			
4	.540	3.859	80.492			
5	.423	3.018	83.510			
6	.356	2.543	86.053			
7	.322	2.299	88.352			
8	.297	2.121	90.474			
9	.273	1.947	92.421			
10	.256	1.831	94.251			
11	.208	1.483	97.482			
12	.189	1.352	98.834			
13	.163	1.166	100.000			

Table 7.7 shows that the first component extracted accounts for over 63% of the variance, and the second component extracted, accounts for just over 8% of the variance within the results, bringing the value of the total variance explained by the two identified components to a total of 72%. Based on the previous word cloud created in Figure 5.4, the descriptors identified by this principal component analysis were rearranged to highlight the two dimensions identified by the analysis as the main assessment criteria, capturing majority of the difference of participant responses to laboratory test bench steering wheel vibration (Figure 7.7).

Figure 7.7 *Word cloud of the two components identified by the laboratory test analysis*

The two main components extracted from the analysis of the laboratory study results were, ‘calm’, and ‘safe’. Table 7.8 presents the component matrix table of each component identified as well as the factor loadings for each variable, which together account for the majority of the possible variance between the participant judgements. Highlighted in green are the latent values of the main extracted components. In addition to each component identified, other descriptors which shoed considerably high factor loadings for each component analysed are Component 1 calm (alarming, smooth, bumpy), and Component 2 safe (sharp, smooth, acceptable).

Table 7.8 *Principal component analysis matrix table of each extracted component of the laboratory study*

Component Matrix[a]

	Component	
	1	2
calm	.872	.168
comfortable	-.865	.061
alarming	.854	.089
smooth	.848	.270
bumpy	.838	.242
acceptable	-.821	.269
regular	-.797	-.040
sharp	.794	.299
pleasant	-.793	.108
powerful	.790	.197
incontrol	.766	-.443
safe	-.720	.509
grippy	.619	-.461

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

As is shown in table 7.8, only a maximum of two components can be extracted from the laboratory data set, which is significantly lower than the number of components identified by the filed study principal component analysis. In addition, none of the descriptors identified as main components in the field study, matched to the descriptors identified by the component analysis of the laboratory study.

To better understand the two main underlying dimensions, further analysis of the two principal components extracted from the results was carried out. Figure 7.8 presents the factor loading plot for the main two components extracted, which is used to identify how the list of semantic descriptors of the scale correlate to the principal components. The figure shows the calm and the safe components represented by each axes and the correlation coefficient of each of the thirteen semantic descriptors.

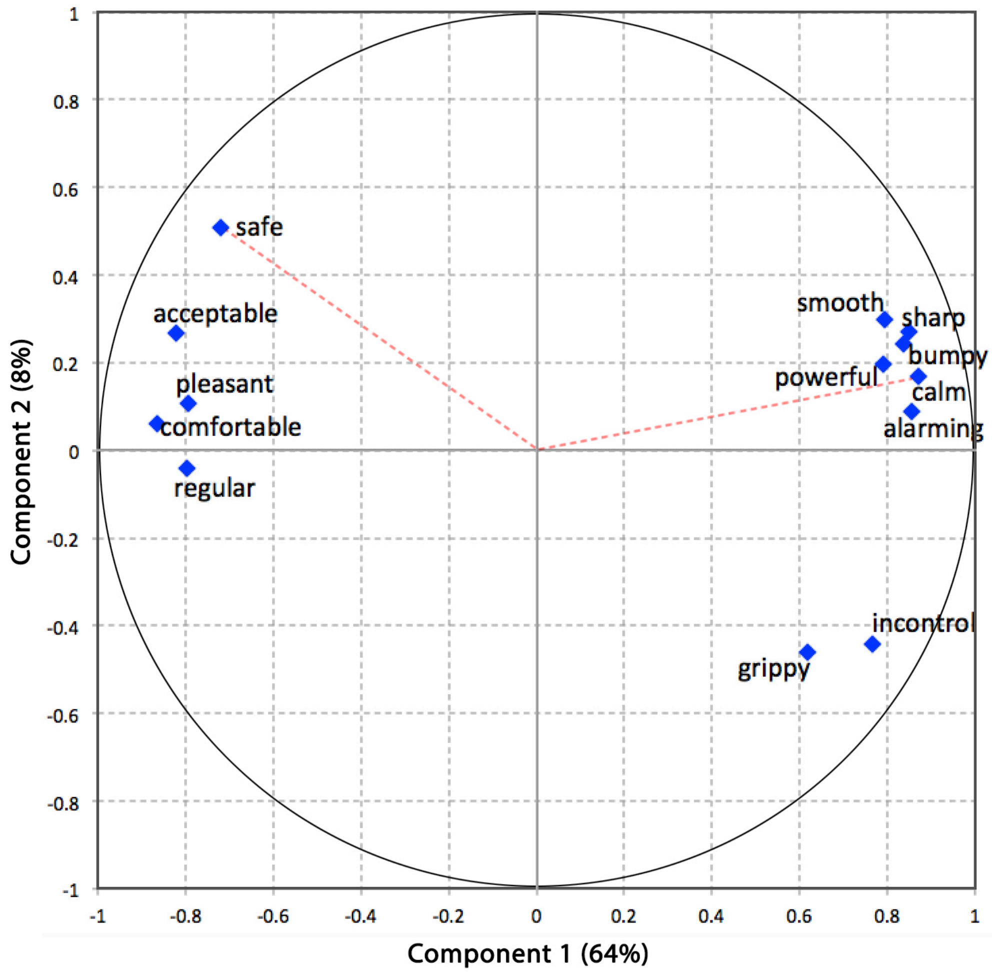


Figure 7.8 *Factor loading plot of the first two components (calm – safe) identified by the laboratory test analysis*

From the figure it is evident that the calm dimension has the highest correlation with the first main principal component (calm) while simultaneously the lowest correlation with the second principal component (safe). Likewise the safe descriptor has the highest correlation with the second principal component (safe) while simultaneously the lowest correlation with the first principal component (calm). The chart therefore highlights that the calm and the safe descriptors closely correlate with the first and the second principal components extracted.

In summary the principal component analysis conducted demonstrated that the characterisation of steering wheel vibration feedback descriptors could be reduced to two underlying dimensions identified as calm and safe descriptors.

7.7 – Laboratory Test Conclusion

The laboratory-based study described in this chapter was carried out in order to measure the participant's judgements to automotive steering wheel vibrations as perceived in a simulated driving scenario, and to assess if the same reliability of the vibrotactile semantic descriptors observed in the field study (Chapter 6) were consistent when compared to driver emotional responses in a laboratory test setting. This study assessed the same semantic differential scale with the same thirteen descriptive pairs obtained from the field study (chapter 5). Five roads surface type acceleration signals were selected from the same eight road surfaces tested in filed study (Chapter 6) that were recorded from three European automobiles, and used as the test stimuli for this study. Two repetitions, of each of the fifteen road surface type acceleration signals were assessed by all twenty-five laboratory test participants.

The gathered laboratory study results were used to create the semantic activation profiles for each of the five road surface type tested in the laboratory, which revealed the level of activation for all thirteen descriptive pairs of the Driver Emotional Semantic scale. Strong similarities were observed between the activation profiles of the Volkswagen Passat and the Mercedes E-Class, while the Volkswagen Polo had very distinct activation profiles compared to the other two automobiles. Further analysis of the results were carried out to identify the principal components of the dimensionality of the driver vibration semantic scale, that together account for the majority of the variance between the data set. Only two components were identified from the laboratory study results, which together accounted for 72% of the total variance observed between the participants judgements of the laboratory bench stimuli. The first main component identified was the calm-aggressive dimension and the second component identified was safe-not safe, none of which however related to the components identified from the principal component analysis of the field study results.

From the laboratory results, it can be concluded that although the Driver Emotional Semantic scale, can be used to accurately capture the variability of the driver emotional responses to steering wheel vibrations of different automotive segments in laboratory setting, however careful consideration needs to be applied to the test protocols in order to enable the comparison of different automotive segments. Although the laboratory experiment was a preliminary study to assess the reliability of the descriptive pairs to measure driver emotional responses in a laboratory setting, the results may not be directly comparable between the automobiles of the field study results due to the differences in the order and number of stimuli assessed by each test participant.

7.8 – Comparison Field Study Results and Laboratory Test Results

Observations between the field study and the laboratory experiment results show that there is a stronger similarity of the activation patterns between all three automobile segments for the field study (Figure 6.4), as oppose to the laboratory test results (Figure 7.5), which show the least similarities between participant judgements of the different automobiles. The main factor contributing to the differences of responses between the field study and the laboratory study dimensionality may be due to the difference of test protocol between the two methodologies. For the field study each participant drove one automobile only on all of the different road surface types, whereas for the laboratory study each participant evaluated all of the stimuli from the three automobiles tested in random order. When subjectively rating sensory stimuli participants tend to compare all of the feedback and evaluate accordingly while considering previous judgements. It is the combination of the assessment of all three automobiles for each test protocol in the laboratory study, which gives the judgements a comparative nature as oppose to the field study where each automobile was evaluated separately.

In addition this effect of change in response could also be due to the lack of the multisensory feedback in the laboratory study as the additional sensory feedback in the field study could have helped the participants to judge the road events differently as oppose to the laboratory study which was used to judge the driver responses in direct relation to the intensity of the steering wheel vibration feedback. Another possible factor contributing to the differences of the dimensionality identified, could be due to the different number of research participants involved in the two studies, with only 25 participants taking part in the laboratory study and a greater number of 120 test participants involved in the field study. With the exception of the VW polo, similarities were observed between the activation levels for some of the road profiles when comparing between both test results, which may confirm that the semantic scale can be used to reliably capture the driver response from the vibration stimuli.

Although there were differences between the two test protocols measuring the reliability of the Driver Emotional Semantic scale, the results from the two studies were combined in Figure 7.8 to compare the activation pattern of each of the three test automobiles for both, the field study and the laboratory experiment.

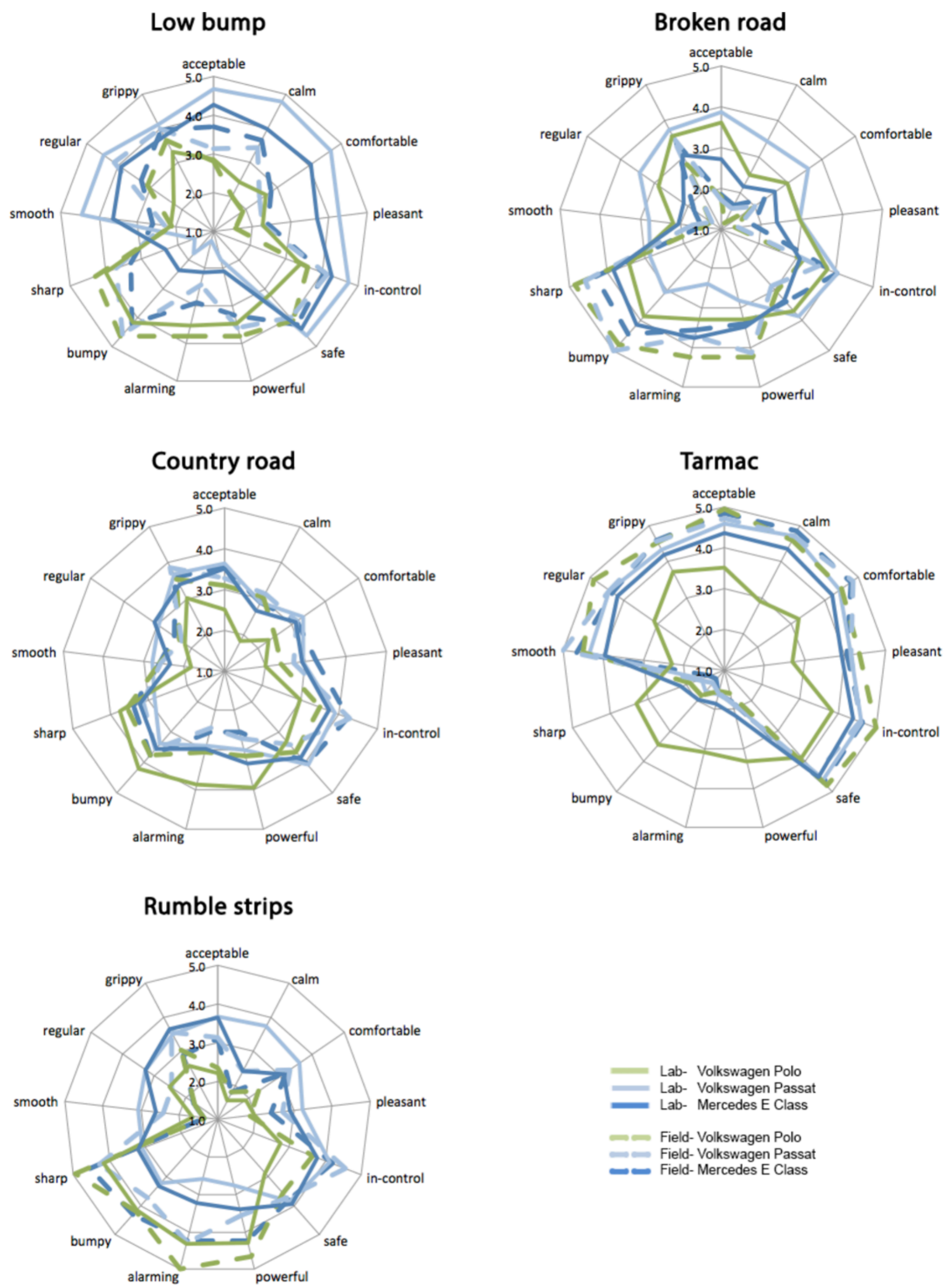


Figure 7.9 *Comparison of the Semantic diagrams showing all three automobile's activation pattern over five road surface types measured in the field study and the laboratory test bench.*

Figure 7.8 confirms the previous statement that the Driver Emotional Semantic scale developed, accurately measures the driver's subjective responses to a large variety of semantic dimensions of vibration feedback, and that the scale could be used to illustrate the activation profiles of the semantics of steering wheel vibration feedback characteristics to differentiate between automotive segments.

When comparing between the automobiles of the two studies, similarities can be seen amongst some of the semantic diagrams, for example for the tarmac road surface, with the exception of the Volkswagen Polo ratings (for the laboratory experiment), the results of the other automobiles correlate closely together among most of the descriptive pairs assessed. Another example of similar activation patterns between the two studies can be seen for the country road surface type, which also shows a close pattern between the automotive segments, with the exception of the Volkswagen Polo (Laboratory Test).

***Figure 7.10** The Semantic Space showing a comparison of each automobiles activation pattern measured in the field study and the laboratory test bench*

In addition to the comparison for each road surface type between the two studies, the mean values across all road types was calculated and plotted in Figure 7.9 so as to compare the activation patterns across all automobiles characteristics. Although great differences are clear between the mean patterns in Figure 7.9, some trends can be observed amongst the semantic space. For example comparisons of the mean activation patterns between each of the studies, show stronger similarities amongst the automobiles of the same study as opposed to the same automobiles compared across the two experiments.

Considering the two Principal Component Analysis results of the field study and the laboratory experiment and the descriptive dimensions identified as the key components accounting for the most of the possible variability of participant responses to vibration feedback, none of the same descriptive dimensions were repeated by the two research analysis. This could be due to the context specific nature of the measuring scale, which may be expected to change with the increased amount of additional sensory modalities perceived in the filed study as compared to the laboratory experiment.

Figure 7.11 *Word cloud of the four components identified in the field study and the two components identified in the laboratory study*

Based on the previous word cloud created in Figure 5.4, the descriptive components obtained by field study and the laboratory experiment result analysis were rearranged to highlight the six dimensions identified as the main assessment criteria, capturing majority of the difference of participant responses, namely: sharp, pleasant, smooth, powerful, calm and safe (Figure 7.10).

To further summarise the research findings of this thesis, figure 7.11 was created to illustrate the three key semantic descriptors identified from the filed study principal component analysis, and to compare the recurring three semantic dimensions of human emotional response as descried by Osgood et al., (1957) and Russell, (1989). The principal components obtained from the laboratory experiment results were not directly compatible with this illustration, as only two components were identified, calm/ aggressive relating to the potency dimension and safe-not/ safe relating to the activity dimension, with no component relating to the evaluation dimension.

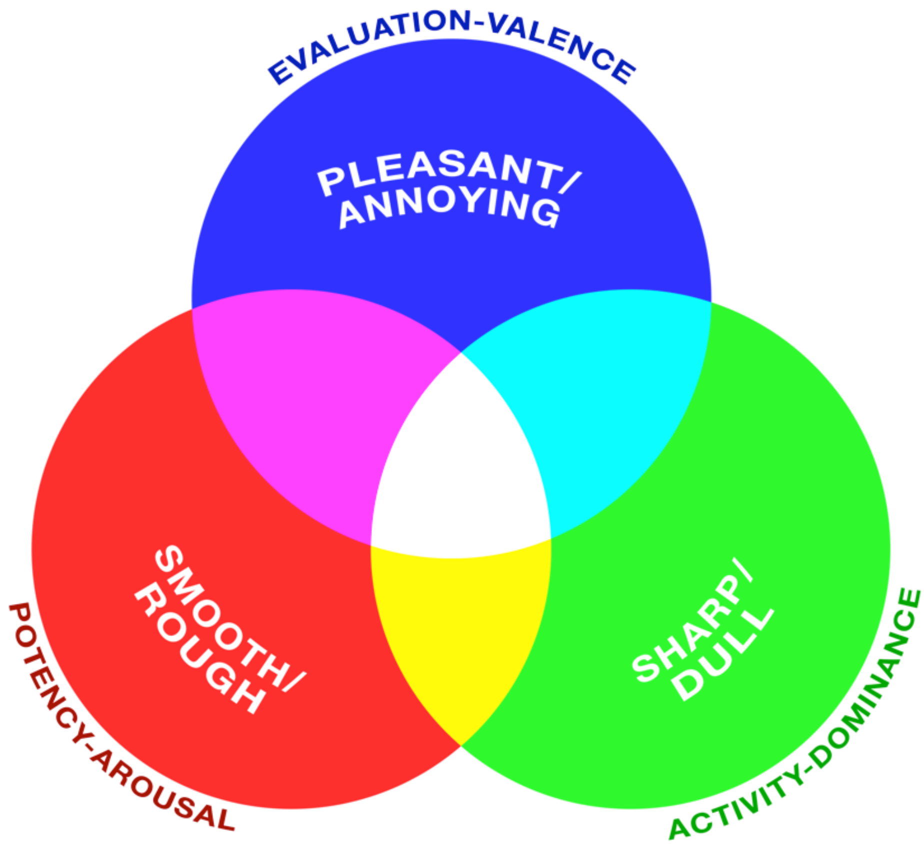


Figure 7.12 *Combination of the dimensions identified in the field study and the existing dimensions of Osgood et al., (1957) and Russell, (1989).*

First attempts have been made to assess the reliability of the descriptive dimensions of the Driver Emotional Sematic scale developed in this thesis. Results suggests that the test methods carried out to answer the research question of this study and the Driver Emotional Semantic scale created, proved reliable to measure and illustrate the participant responses of automotive steering wheel vibrations in real road scenarios and laboratory test bench setting. Although the same semantic descriptors categorised by the principal component analysis in the field study scenario, are not repeatable when comparing to assessments of laboratory test bench responses.

The assessment of reliability of the descriptive pairs for the field study experiment confirmed the conclusions made by Osgood et al., (1957), which state that the three recurring basic dimensions to capture the human emotional response can be categorised as evaluation, (pleasant – annoying), potency (smooth – rough), and activity (sharp – dull), all of which were found in this work closely related to the first three components identified by the field study. No such similarities were identifiable by laboratory study principal component analysis as only two components were extracted. Further suggesting that the field study has possibly captured, with greater accuracy the driver semantic experience associated to automotive steering wheel vibration character as compared to the laboratory experiment and that these specific dimensions need to be validated to fully develop and establish the Driver Emotional Semantic Scale as illustrated bellow in figure 7.12.

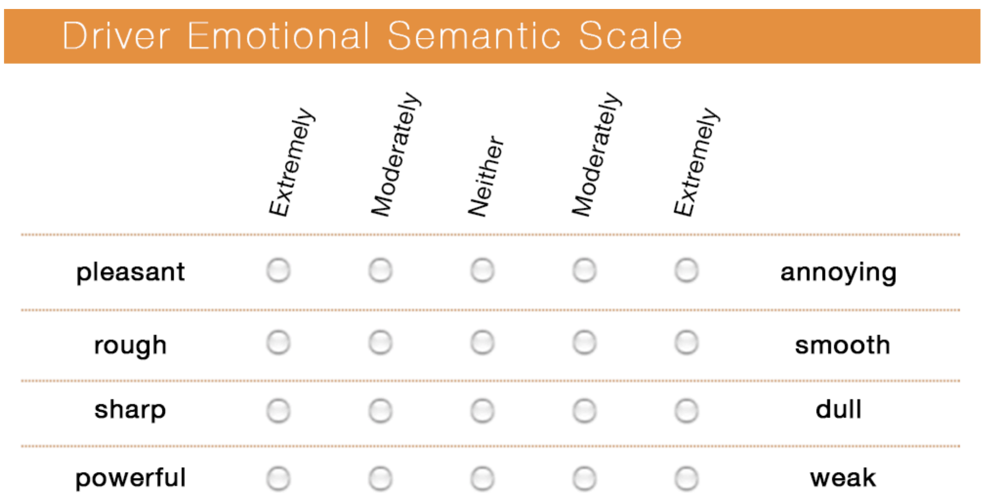


Figure 7.13 *The final Driver Emotional Semantic Scale with the four key components proposed in this thesis*

In summary the methodological approach for the laboratory test was chosen as a preliminary study to assess the reliability of the scale by comparing it to the field test results. The limitations of this approach showed that the two studies were not directly comparable due to the change of variables of the test protocols, although the road surface types used in the laboratory study had the same replicated vibratory stimuli as recorded from the field study.

The main differences were noted in the test participants' response ratings which appeared to be more influenced by the road type in the field study as opposed to the laboratory test whereas the influence in the test participants' response ratings were mainly influenced by the differences between the automobile type. The cause of this issue can be attributed to the comparative nature of the laboratory test setup as can be seen from table 7.5, which shows that some of the lowest intensity road signals from one automobile (Polo/ Low bump r.m.s.=1.5) can be nearly similar to high intensity road signals for another automobile (Passat/ Country road r.m.s.=1.8). Therefore it is suggested for future research that, while a laboratory test setting still represents a good way to assess differences amongst automobiles and stimuli, participant ratings associated to automotive driving experiences should be better assessed using real world driving field studies so as to capture a more direct and uninterrupted assessment of road condition.

To allow for a better comparison of the differences between the two test scenarios (laboratory and field), an extensive laboratory study would need to be carried out with 20 participants for each of the six automobiles used to asses all of the eight roads similar to the field study protocol stimuli, which will allow for a better replication of the field test procedure which should hypothetically give similar semantic diagrams from the laboratory ratings as compared to the field study sematic diagrams.

Chapter 8 – Conclusions and Future Work

8.1 – Summary of Research Findings and Conclusions

The gap that this research work tries to cover is in the lack of a formal assessment criteria for driver emotional response to automotive steering wheel vibration and the lack of a defined semantic vocabulary used to describe the perceived feeling of vibration feedback. Therefore the main question addressed by this research thesis was "How can the driver emotional response to steering wheel vibration be assessed?". The research carried out in this work has gathered the underlying semantic descriptors and dimensionality of responses that drivers use to associate to perceptions of steering wheel vibration feedback, which has helped to formulate the driver emotional semantic scale, necessary to capture the majority of the possible variability of the drivers subjective responses. This chapter summarises the individual research questions set out to answer in by this thesis (Chapter 1), and the main research findings discovered, leading to a summary of the conclusions and future work of this study.

a) Are there any differences between the expected emotional ratings obtained from the information recalled from the driver's long-term memory and the experienced emotional ratings obtained from the felt experience when holding a vibrating steering wheel?

A comparison of the two experimental test method results (Chapter 4), based on a questionnaire survey and a laboratory test were carried out to identify if a correlation exists between the emotional response measured from the expected driver's perception of the vibration associated to the sight of a picture representing different road surface types (questionnaire survey) and the emotional response measured as experienced driver's perception of the felt vibration feedback simulated by a vibration steering wheel (laboratory test). The valence and arousal dimension ratings for 17 steering wheel vibration road profiles were assessed. A comparison of the two dimensional affective spaces of the valence and arousal scale for the laboratory test (Figure 4.12) and for the questionnaire survey (Figure 4.3), suggests a similar trend between the two graphs. The similar trend in the linear correlations of the two data plots suggests that irrelevant of whether the responses are perceived or memory based, high levels of emotional arousal (excited feeling) of steering wheel vibration are mostly associated with low levels of emotional valence (unpleasant feelings), and that high levels of emotional valence (pleasant feelings) are associated with low levels of emotional arousal (calm feelings) of the vibration. This result seems to be consistent with an underlying bimotivational structure of affective judgements which involve two systems of motivation, each varying towards either a high-arousal pleasant or a high-arousal unpleasant dimension (Greenwald et al., 1989).

b) How does the vibration stimuli intensity affect the emotional response of the valence and the arousal dimension?

Experiment 2 (see section 4.3) also focused on identifying what form of relationship existed between the valence and the arousal dimensions of the human emotional response to steering wheel vibration acceleration intensity. In particular, low intensity steering wheel vibration stimuli with acceleration values less than 0.30 r.m.s. m/s^2, such as those of the tarmac, concrete, slabs and low bump road conditions of the present study, elicited high levels of valence and low levels of arousal suggesting thus a more pleasant and calmer emotional response than higher intensity steering wheel acceleration stimuli. Whereas high intensity steering wheel vibration stimuli with acceleration values more than 1.70 r.m.s. m/s^2, such as those of the broken concrete, broken lane and country lane driving conditions, were characterised by low levels of valence and high levels of arousal suggesting thus an unpleasant and aroused emotional response.

Considering the results illustrated in Figure 4.14 and Figure 4.15 which show that participant emotional ratings for most road surface conditions assessed, mainly cover a small area of the two dimensional charts especially for the arousal scale, which suggest that the two basic dimensions of valence and arousal may not suitable to measure the full range of the driver emotional response and there could possibly be other descriptors better suited for measuring all of the aspects associated to the driver emotional vocabulary of vibration feedback. This further highlights the need to define the emotional semantic descriptors for assess steering wheel vibration.

c) What are the main vibrotactile semantic descriptors that can be used to assess the human emotional response to automotive steering wheel vibration in real driving scenarios?

This question was addressed in Chapter 5 of this thesis, which gathered the emotional semantic vocabulary of vibration as defined by drivers when assessing automotive steering wheel vibration feedback from various road surface types in real driving scenarios. From this field study, a total of 153 different vibrotactile descriptors were gathered, which were analysed and put through a merging process in order to condense and select a more manageable list of key assessment criteria. A Diver Emotional Semantic scale was developed (Figure 5.6) using the final list of 13 descriptive pairs gathered from the verbalisation task of the field study. The 13 descriptive pairs obtained were: **aggressive/ calm, alarming/ unalarming, comfortable/ uncomfortable, out-of-control/ in-control, pleasant/ annoying, powerful/ weak, safe/ not-safe, acceptable/ unacceptable, bumpy/ even, regular/ irregular, rough/ smooth, sharp/ dull, and slippery/ grippy**. It was suggested that using a larger number of descriptive pairs as the assessment criteria, the developed Driver Emotional Semantic rating scale should measure with greater accuracy the key driver semantic dimensions to automotive steering wheel vibrations. To test the reliability of the thirteen descriptive pairs of the rating scale in real road scenarios and laboratory test setting, the scale was evaluated further in the last two experiments of this thesis (see Chapter 6 and 7). The main vibrotactile semantic descriptors that can be used to assess the human emotional response to automotive steering wheel vibration of real driving scenario were found to be four: **pleasant, smooth, sharp and powerful**, as address in the following research question.

d) Are the identified vibrotactile semantic descriptors reliable when used in real road scenarios?

Chapter 6 descried the field study carried out to identify if the thirteen descriptive pairs defined in the Driver Emotional Semantic scale are reliable when measuring the driver emotional responses to steering wheel vibration feedback across different automotive segments. The results established the semantic activation profiles for each of the eight road surface types, showing the level of activation pattern of each automobile's vibration feedback characteristics for all thirteen descriptive pairs. This suggests that the Driver Emotional Semantic scale developed in Chapter 6, could accurately capture the measurable driver emotional responses to steering wheel vibrations of different automotive segments. A principal component analysis was carried out to identify which of the semantic dimensions account for the majority of the variance between the participant's judgements, in turn, grouping the main vibrotactile dimensions describing the driver's perceptions of steering wheel vibration feedback. The results suggest that the four descriptors identified (namely: **sharp, pleasant, smooth and powerful**) account for over 80% of the total variance observed between the participant's judgements of the eight steering wheel vibration feedback. The components identified by the analysis of the field study results are consistent with the basic recurring dimensions defined by Osgood et al., (1957) to capture human emotional responses can be categorised as evaluation (Component 2 – **pleasant/ annoying**), potency (Component 3 – **smooth/ rough**), and activity (Component 1 – **sharp/ dull**).

e) Are the identified vibrotactile semantic descriptors consistent when used in a laboratory test setting?

The final question addressed by this research methodology involved another experimental evaluation of the developed scale, aimed to identify the consistency and reliability of the semantic descriptors to measure the driver emotional response in a laboratory setting, and to identify if the same dimensionality of responses can be observed between the two experimental test methods (Chapter 6 and Chapter 7). Semantic activation profiles were created from the laboratory results for each of the five road surface types tested, showing the level of activation pattern of each automobile's vibration stimuli assessed using the thirteen descriptive pairs. Results suggests that the Driver Emotional Semantic scale developed in this thesis, could also be used to accurately capture the measurable driver emotional experience to steering wheel vibrations in laboratory test setting. The principal component analysis of the laboratory results extracted only two components from the participants judgements, which together accounted for 72% of the total variance observed between the results of the test bench experiment. The first main component identified was the **calm/ aggressive** dimension and the second component identified was **safe-not/ safe**, none of which however related to the components identified from the principal component analysis of the field study results (Chapter 6). Results suggests that the Driver Emotional Semantic scale developed could prove reliable to measure the participant responses of automotive steering wheel vibrations in real road scenarios and laboratory test bench setting, although the key semantic dimensionality of two methods is not repeatable, suggesting that the field study has possibly captured with greater accuracy the driver semantic experience of automotive steering wheel vibration character as compared to the laboratory experiment.

8.2 – Future Work

For the manufacturers of automotive steering systems and of other automobile components this study provides psychophysical relationships to approach the design of steering systems by identifying the possible importance of stimuli properties towards the emotional experience of vibration which arrives at the interface between the steering wheel and the driver. These stimuli must capture attention and obtain fast and intuitive responses from the driver in critical situations, while maintaining an appropriate level of information load which makes the driving experience pleasant and relaxing in non-critical situations.

The Driver Emotional Semantic scale developed by this research methodology contributes to the understanding on how the driver emotional response to steering wheel vibration can be assessed and what are the key assessment criteria for capturing the driver responses of semantic emotional descriptors to automotive steering wheel vibration. This study aimed to identify the consistency of the reliability of the descriptive dimensions of the Driver Emotional Sematic experience in two different automotive testing conditions of real road field study and laboratory test setting.

While the current study has provided some first items of information on deciphering the descriptive vocabulary and the language of communication between the driver and the felt vibration emitted from the steering wheel, further research is required in order to build a toolkit or a dictionary that will allow automotive designers to tailor the feedback emitted from the vibrotactile touch points of the automobile. This could help to greatly improve the steering feedback characteristics and the felt quality of the overall automobile leading to a better and enhanced driving experience especially in the case of new drive by wire and hydraulic systems which is gradually decreasing. Further research that could extend the existing study is addressed bellow:

- **External validation of the newly developed Driver Emotional Semantic Scale:** Further tests are needed in order to test the validity of the descriptive dimensions of the proposed measurement scale in real road scenarios. An exact replication of the field study test protocol using automobiles of different make and class, driving on different road type of those used in this study would then provide an external validation of the proposed Driver Emotional Semantic scale.

- **Number of best descriptors to capture the human emotional response to steering wheel vibration:** A detailed assessment of the semantic dimensions identified from the principal component analysis of the field study results (sharp, pleasant, smooth and powerful) and the laboratory experiment results (calm and safe) may reveal their significance to measure the driver emotional response to automotive steering wheel vibration, and to focus on a smaller number of assessment dimensions with the aim of further merging the list of descriptors to include only the dimensions necessary to measure the driver emotional response

- **Measuring the advantages of the newly developed Driver Emotional Semantic Scale compared to other scales:** Comparison studies assessing the effectiveness of the Driver Emotional Semantic scale in relation to other emotional measurement scales for measuring the driver emotional response to automotive steering wheel vibrations may reveal the advantages of using the proposed scale over other scientific methods currently available.

- **To identify what steering wheel vibration signal properties can be used to control the human emotion response to vibration:** Once the scale validation is fully established, additional research is needed in order to extend the current study to identify the vibration signal properties, which contribute to the change of driver emotional response and that could be used to elicit a certain type of response. The current results show that the intensity of the steering wheel vibration signal does not appear to be the only contributing factor of the acceleration signal to the change in the driver subjective response, and that other signal properties could be influential such as the presence of high peak events or high frequency band amplitudes.

- **To replicate in the laboratory test bench, the same test protocol as carried out in the field study:** For better comparison of the correlations between the two test scenarios (laboratory test and field study), an extensive laboratory study should be planned out with 20 participants for each of the six automobiles used to asses every one of the eight roads as tested in the field study, which will allow for a better replication of the field test procedure and should hypothetically generate similar results from the laboratory ratings as compared to the field study sematic diagrams.

Glossary Definitions

This section defines the terminology used in this thesis:

Attention

Attention is the mental ability of taking notice or considering of someone or something; the regarding of someone/something as interesting or important, whilst ignoring other things. Attention as behaviour is related with the responses of the attention or arousal systems of the brain and also with the neuromuscular responses that govern the orientation of the eyes, ears, and other sensory surfaces of the body.

Comfort

Comfort has become a leading motivator in product design and is synonymous with usability. It is defined as state of physical ease and freedom from constraint or pain.

Driver Experience

Driver experience in this thesis refers to the contained feelings and emotional states of the automobile driver that are elicited by the multisensory feedback from the driving environment.

Driver Distraction

Driver distraction refers to the diversion of attention from activities crucial for safe driving to a competing activity, such as, smoking, mobile phone use, eating or drinking, searching for items, etc. Definitions of distraction differ in how driver's state (e.g. fatigue or drunk) and activities/objects linked to driving are classified, together with how distraction in relation to the concept of inattention is interpreted.

Driver Safety

Refers to safely driving on road ensuring no harm is caused to other road users as well as the driver himself.

Emotion

Emotion is a complex psychophysiological experience that interacts with biochemical (internal) and environmental (external) influences. Appearance, sound, haptic and tactile are the four key contributing perception receptors that evoke an emotional experience, when considering products

Emotional Response

Emotional response is Information specified about the self, it is impulsive, momentary and autonomous. Every product will cause an emotional response on each of Norman's (2004) three levels; visceral, behavioural and reflective.

Experience

Experience refers to the nature of the events someone or something has endured. When considering products, experience is to think beyond the object, as, physical artefacts will be trivial without considering the larger contexts and meanings behind customer's experiences.

Feedback

Feedback is used as a basis for improvement by providing information regarding reactions to a product, or a person's performance of a certain task and the like.

Meaning

Meaning is construction built up from dialogues with one's inner self (superego), with the external world (cosmos) and with other people (social). It can also be defined as the values or interpretations that are communicated through people, products or interactions. Is what the source or sender expresses, communicates, or conveys in their message to the observer or receiver, and what the receiver infers from the current context.

Perception

Perception refers to our understanding of the world around us. Information is gathered through our five sense organs, whilst perception enhances meaning to the sensory inputs. There is never an exact recording of the even or situation thus the process of perception is subjective in nature.

Quality

Quality is difficult to accurately outline as it is dependent on personal choice and preference but it is a term often used to describe the standard of something by comparison with other things of similar kind.

Semantic Dimensions

The term semantic dimension in this thesis refers to the descriptive pairs used for assessment in different rating scales such as the thirteen descriptors obtained in chapter 5.

Situation Awareness

Situational awareness refers the knowledge of what is happening around you, for the ability to understand how information, events and your individual actions will impact goals and objectives in the future or immediately.

Sound

Sound is a useful tool for enabling and augmenting product interactions. It is a mechanical wave transmitted through the air or another medium (liquid or even solid), composed of frequencies within the range of hearing that ultimately causes vibrations, which stimulate the sensation in organs.

Tactile

Tactile pertains to an understanding through the sense of touch; the largest sensory organ in the body. Touching and being touched are integrated in one phenomenon and it is our method of getting close and interactive with our products.

Vibration

Vibration is the mechanical oscillations of a structure about an equilibrium point. The oscillations can be either random or periodic, such as, the movement of a tire on a gravel road or the motion of a pendulum.

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Appendices

Appendix 1

Questionnaire on Emotional Expectations of Steering Wheel Vibration in Automobiles

Experimenter's detail: Mr Arber Shabani & Dr Marco Ajovalasit
Perception Enhancement Research Group, Brunel University, London.
Tel : 07999469500 & 0189 526 7134

The objective of this research is to identify what emotional responses people expect to perceive from the steering wheel vibration of various driving situations. All information will be used for research purposes only and will remain strictly confidential. Please remember to answer all the questions of this survey and to submit when completed.

Section A – Personal Information

First Name: ________________________________ Family Name: ____________________________

Age (years): ________________________________ Gender: Male ☐ Female ☐

Weight (kg): ________________________________ Height (cm): ______________________________

1) Do you consider yourself as a professional driver (e.g. racing, testing, taxi or commercial vehicles)?

Yes ☐ No ☐

If Yes, please provide details of driving activity:

____

2) How many years of driving experience do you have since obtaining your driving license (years):___

3) What type of vehicle do you normally drive:

Car ☐ Van ☐ MPV ☐ Truck/Bus ☐ 4x4/SUV ☐

4) Do you have any condition which you feel may modify your perception of visual, sound or tactile stimuli?

Yes ☐ No ☐

*If Yes, please give details:*____

PLEASE TURN OVER

Section B – Emotional Expectation of Steering Wheel Vibration

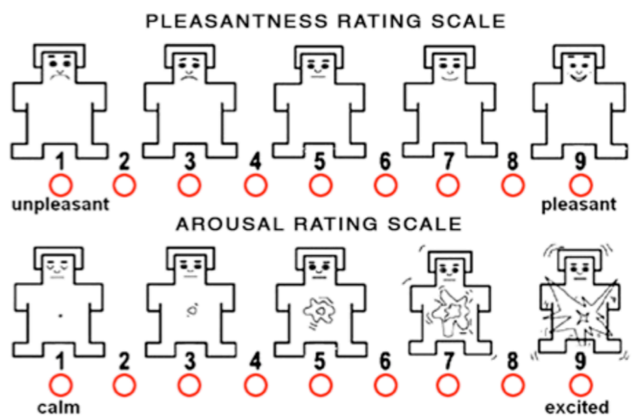
Based on your driving experience please indicate the emotional feeling you associate with the steering wheel vibration of each of the driving situations listed below. (Please provide a number for each driving situation using the Rating Scale presented.

Rating Scale Usage: *the Rating Scale provided consists of a set of symbolic graphical representations of the human body under various degrees of emotional response. Please choose a numerical value from 1 to 9 to indicate both the level of emotional pleasantness and the level of emotional arousal (excitement) you associate with the steering wheel vibration of each of the driving situations. To facilitate assessment, a close-up view of each driving situation is also shown below.*

1. Tarmac, (vehicle speed 96 km/h)

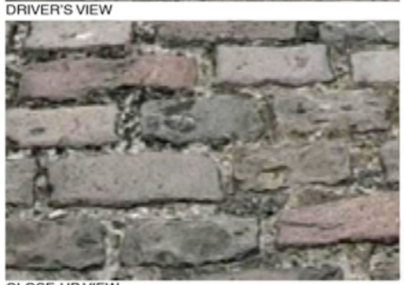
DRIVER'S VIEW

CLOSE-UP VIEW

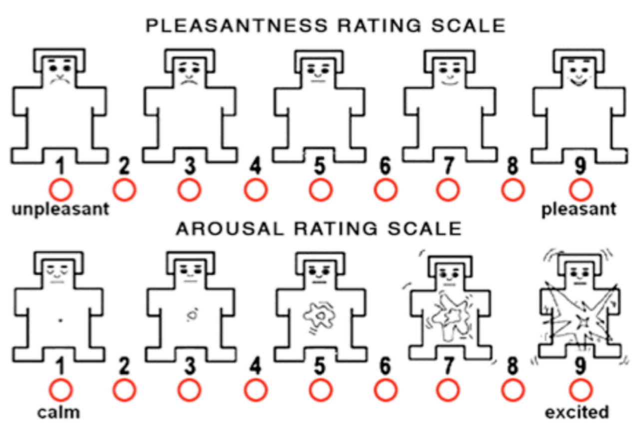


2. Cobblestone, (vehicle speed 30 km/h)

DRIVER'S VIEW



CLOSE-UP VIEW



PLEASE TURN OVER

Appendix 2

	Tarmac		Concrete Road		Slabs Road		Cobblestone		Low Bump Road		Stone on Road		Expansion Joints		Bump Road	
	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal
Participant 1	9	1	9	1	7	3	1	7	5	3	5	3	3	5	6	2
Participant 2	8	1	9	1	8	3	1	6	5	3	4	4	4	7	4	6
Participant 3	9	1	8	2	7	2	4	3	7	2	6	3	6	3	5	3
Participant 4	8	3	4	6	3	5	3	7	4	7	4	7	3	8	5	5
Participant 5	9	1	9	1	6	5	6	3	6	3	8	2	9	3	5	3
Participant 6	5	1	6	1	6	3	4	2	5	3	5	4	5	1	6	3
Participant 7	9	2	9	1	7	3	1	8	3	5	5	4	5	5	2	5
Participant 8	7	4	9	1	7	3	2	6	7	4	7	2	5	3	5	6
Participant 9	9	2	9	1	7	3	3	6	6	2	8	3	6	2	5	4
Participant 10	7	3	8	1	8	1	3	6	7	3	6	3	7	3	5	4
Participant 11	8	2	8	2	7	3	3	7	4	5	3	5	5	4	4	5
Participant 12	6	6	7	3	5	4	3	9	1	6	1	5	1	7	1	1
Participant 13	8	2	8	2	7	3	4	7	5	4	4	6	5	4	5	4
Participant 14	9	2	8	2	7	2	6	4	2	5	5	4	4	4	4	4
Participant 15	7	7	7	7	1	1	3	2	4	3	1	1	5	5	2	3
Participant 16	9	2	7	6	4	2	4	2	5	2	4	2	6	2	5	3
Participant 17	9	1	7	3	6	4	3	8	1	9	2	8	7	3	4	5
Participant 18	9	1	9	1	7	3	4	5	6	4	5	4	3	6	4	7
Participant 19	7	5	9	1	6	4	3	2	5	5	1	8	1	5	4	7
Participant 20	8	5	6	4	3	3	2	4	2	3	3	4	3	3	3	4
Participant 21	9	2	9	1	7	3	2	9	6	4	6	4	3	7	4	7
Participant 22	9	2	9	1	6	3	6	2	6	2	6	4	6	1	5	3
Participant 23	9	2	9	1	8	2	8	2	7	2	5	4	5	4	7	4
Participant 24	7	5	9	2	6	3	3	8	6	4	7	3	5	7	3	5
Participant 25	8	1	9	1	7	3	4	7	7	3	7	5	7	3	7	4
Participant 26	9	3	9	5	7	2	4	3	7	4	6	3	7	4	6	4
Participant 27	8	2	9	1	8	1	3	5	6	2	7	3	6	3	6	4
Participant 28	9	1	9	1	7	3	2	7	6	4	5	4	3	6	4	7
Participant 29	8	4	9	1	8	2	3	5	7	2	7	3	6	3	6	4
Participant 30	9	1	9	1	8	2	6	6	7	2	7	3	7	3	8	2
Participant 31	8	2	8	1	6	1	6	2	7	1	7	2	7	2	6	3
Participant 32	8	1	9	1	8	3	5	6	8	2	8	3	7	2	7	3
Participant 33	9	1	9	2	8	2	4	5	8	2	8	2	7	3	7	2
Participant 34	8	1	9	1	8	1	6	4	8	2	8	2	7	2	8	3
Participant 35	1	3	9	1	4	3	4	5	6	2	5	2	9	1	1	6
Participant 36	8	2	8	1	6	1	6	2	7	1	7	2	7	2	6	3
Participant 37	9	2	9	1	6	2	5	4	8	2	7	2	7	3	7	4
Participant 38	8	4	9	2	8	4	5	6	8	2	7	4	7	4	7	5
Participant 39	9	1	9	2	7	2	3	5	8	2	7	3	7	3	7	3
Participant 40	9	1	9	2	7	2	3	5	8	2	7	3	7	3	7	3
Participant 41	9	2	9	1	8	3	6	6	8	2	8	3	8	2	7	3
Participant 42	9	1	9	1	7	4	5	6	8	3	6	3	6	2	6	3
Participant 43	7	3	7	7	7	6	4	6	6	5	4	7	4	5	6	5
Participant 44	9	1	9	2	8	2	6	2	7	4	7	2	7	3	6	5
Participant 45	9	1	9	1	7	4	4	5	7	2	7	3	7	3	6	4
Participant 46	9	5	8	5	5	5	1	5	3	5	4	5	4	5	4	5
Participant 47	9	1	9	1	7	2	3	7	7	2	6	3	6	4	6	3
Participant 48	7	1	9	5	7	2	3	8	5	3	6	3	4	7	5	4
Participant 49	7	3	8	3	5	5	2	7	4	6	1	6	5	5	1	7
Participant 50	8	2	9	1	8	1	3	3	6	2	6	2	5	3	6	3
Participant 51	7	2	6	2	5	7	3	5	5	1	4	4	4	2	5	2
Participant 52	8	4	9	2	6	2	3	5	8	2	7	3	8	2	7	5
Participant 53	8	1	9	1	6	3	3	8	7	4	5	3	6	2	5	4
Participant 54	7	2	8	1	6	3	4	6	6	3	7	3	6	3	5	5
Participant 55	9	2	8	1	5	4	3	7	6	3	5	3	5	5	4	4
Participant 56	8	1	9	1	7	2	4	6	7	3	7	4	7	4	4	7
Participant 57	7	2	8	5	7	4	3	8	8	2	4	5	4	5	6	3
Participant 58	9	1	9	1	8	2	5	4	6	2	6	4	6	4	5	4
Participant 59	8	2	8	2	7	3	4	7	5	4	4	6	5	4	5	4
Participant 60	9	1	9	1	6	5	3	6	7	2	6	4	7	3	3	6
Participant 61	7	1	8	1	7	4	4	7	7	2	6	3	6	3	4	5
Participant 62	9	1	9	1	7	3	2	7	8	2	7	3	6	2	4	6
Participant 63	8	1	8	2	5	4	4	6	7	3	7	3	8	2	5	5
Participant 64	9	1	9	1	7	3	5	4	8	2	7	2	7	3	4	5
Participant 65	8	3	9	1	7	3	4	5	6	3	5	3	6	3	5	4
Participant 66	8	2	8	2	7	3	4	5	6	3	6	4	5	4	5	4
Participant 67	7	2	7	1	7	3	4	6	6	2	5	4	5	4	6	4
Participant 68	9	2	8	2	6	4	3	5	5	4	3	3	5	4	4	6
Participant 69	9	3	9	2	6	5	4	4	6	2	5	3	6	2	5	5
Participant 70	8	1	9	2	6	3	3	5	5	4	6	4	4	5	5	4
Participant 71	7	3	8	2	6	4	4	6	3	5	5	2	4	4	5	3
Participant 72	7	1	8	1	7	5	3	5	4	4	5	5	5	6	5	5
Participant 73	9	1	5	1	5	1	1	1	5	1	5	1	5	1	5	1
Participant 74	9	4	4	3	5	4	1	9	1	9	6	5	1	9	2	9
Participant 75	9	2	6	3	3	6	1	9	3	8	2	7	1	8	1	9

	Manhole Road		Cats Eyes		Broken Road		Rumble Strips		1cm Metal Bar		Transverse Joints		Broken Concrete		Broken Lane		Country Lane	
	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal
Participant 1	5	2	2	6	3	4	5	2	3	4	8	2	6	2	5	2	8	1
Participant 2	7	3	2	8	4	5	5	3	4	5	5	3	6	2	7	3	8	5
Participant 3	5	2	5	3	7	2	7	2	6	2	7	7	6	4	7	2	7	2
Participant 4	2	7	4	7	3	8	4	5	5	6	4	6	3	7	3	7	4	6
Participant 5	8	3	7	3	5	5	9	1	5	4	7	5	8	2	6	3	7	6
Participant 6	4	3	6	3	6	2	8	2	5	4	5	4	6	2	5	1	4	3
Participant 7	3	5	3	4	3	5	3	5	4	4	3	5	5	4	1	8	4	5
Participant 8	3	4	3	6	6	2	7	1	5	4	9	2	8	1	7	2	8	2
Participant 9	4	5	4	4	7	2	7	2	7	2	9	6	7	3	7	2	8	3
Participant 10	4	5	4	5	5	3	6	3	8	3	9	7	5	4	5	3	7	2
Participant 11	4	5	4	5	4	5	3	7	6	3	6	4	5	4	6	2	5	4
Participant 12	1	9	3	1	5	2	4	5	1	5	9	1	5	4	5	1	5	3
Participant 13	3	7	5	4	5	4	4	7	3	7	7	3	5	5	5	4	7	3
Participant 14	5	3	3	5	6	4	6	3	3	4	6	3	6	3	5	3	6	3
Participant 15	1	1	4	3	2	1	7	5	5	5	1	1	3	3	5	3	4	3
Participant 16	5	3	4	5	5	4	5	4	5	3	4	3	5	4	6	2	3	4
Participant 17	1	9	3	9	3	3	3	6	1	7	7	3	1	8	7	4	6	3
Participant 18	5	4	6	3	4	6	6	6	2	7	7	3	6	5	5	3	8	2
Participant 19	2	7	2	7	2	7	7	2	4	6	8	2	6	4	3	6	4	6
Participant 20	3	3	3	3	4	3	4	4	3	3	4	3	3	3	2	3	3	3
Participant 21	5	4	6	4	4	6	6	8	2	7	7	2	4	6	5	3	7	3
Participant 22	2	9	6	4	7	3	4	5	8	1	7	2	6	4	8	1	7	3
Participant 23	4	7	4	4	8	2	6	5	7	3	5	8	5	5	7	2	7	3
Participant 24	6	4	1	5	6	3	5	3	6	2	7	6	5	4	5	4	8	3
Participant 25	5	4	3	6	7	5	6	4	6	4	8	7	8	2	6	3	7	3
Participant 26	4	4	4	4	6	3	7	2	7	4	8	5	7	3	6	3	7	4
Participant 27	4	4	4	5	7	2	7	5	7	3	8	6	7	2	7	2	7	1
Participant 28	5	4	6	4	4	6	6	6	2	7	7	3	6	5	5	3	8	2
Participant 29	4	4	3	4	8	2	5	3	6	3	8	6	6	3	7	3	8	4
Participant 30	4	3	6	3	8	3	7	2	7	2	9	7	8	2	8	1	8	3
Participant 31	5	3	5	2	7	2	6	2	6	2	8	4	7	2	8	2	8	1
Participant 32	6	4	6	4	8	1	8	2	7	2	8	4	8	3	8	2	8	2
Participant 33	4	5	4	5	7	3	8	3	8	2	7	6	8	3	8	3	9	2
Participant 34	7	3	5	3	8	2	8	2	7	2	9	4	8	2	8	2	9	2
Participant 35	1	8	1	8	6	3	1	9	1	3	8	1	4	3	4	3	3	5
Participant 36	5	3	5	2	7	2	6	2	6	2	8	4	7	2	8	2	8	1
Participant 37	4	5	3	5	5	5	6	3	6	2	9	6	8	3	7	2	7	2
Participant 38	4	6	4	5	7	3	7	5	7	4	8	6	7	4	8	3	6	4
Participant 39	6	4	3	6	8	2	7	4	7	3	9	4	8	3	8	3	8	2
Participant 40	6	4	3	6	8	2	7	4	7	3	9	4	8	3	8	3	8	2
Participant 41	6	4	5	4	8	1	8	3	7	2	8	7	8	2	7	2	8	2
Participant 42	4	7	4	7	7	2	6	3	7	3	8	4	6	4	8	2	7	2
Participant 43	6	4	5	6	5	5	6	5	4	5	6	5	6	5	5	5	5	6
Participant 44	5	4	4	6	8	3	7	3	7	3	8	5	8	3	8	2	7	2
Participant 45	5	5	3	7	8	3	6	3	7	4	9	5	6	4	8	2	7	2
Participant 46	4	6	3	5	3	6	4	6	2	7	7	7	4	5	3	6	8	7
Participant 47	4	6	3	8	8	1	5	5	6	4	9	4	7	3	7	4	8	2
Participant 48	7	2	6	3	7	4	7	2	5	3	8	3	6	4	5	3	9	3
Participant 49	1	5	1	6	1	6	3	4	4	4	4	4	1	5	1	6	3	4
Participant 50	4	4	4	4	7	3	6	3	5	3	8	3	8	2	8	2	8	2
Participant 51	5	2	5	2	4	5	5	8	4	3	4	7	3	4	5	2	5	3
Participant 52	5	4	4	5	7	3	6	4	7	4	9	4	8	3	8	3	6	4
Participant 53	4	7	4	5	6	3	5	3	5	5	6	4	4	5	7	3	7	4
Participant 54	4	4	5	4	6	4	6	4	3	4	6	4	4	3	7	2	5	3
Participant 55	4	3	3	4	5	5	4	4	4	5	7	3	5	4	6	4	7	4
Participant 56	5	5	5	5	6	5	7	3	7	2	7	4	6	4	7	4	8	4
Participant 57	4	6	3	7	8	3	7	4	7	3	8	5	7	4	8	2	7	2
Participant 58	6	5	5	4	6	3	7	2	7	3	6	4	8	3	8	3	7	4
Participant 59	3	7	5	4	5	4	4	7	3	7	7	3	5	5	5	4	7	3
Participant 60	5	4	3	7	4	6	4	7	7	2	6	4	6	4	6	4	3	5
Participant 61	4	5	4	6	7	3	5	4	5	3	8	6	6	3	7	4	8	3
Participant 62	3	6	6	5	7	3	3	6	6	3	7	4	5	4	7	3	5	4
Participant 63	5	4	4	6	5	5	5	4	6	3	8	7	7	3	6	5	6	5
Participant 64	3	5	5	5	6	4	3	6	8	1	8	5	6	3	8	2	7	5
Participant 65	4	4	4	4	4	6	5	6	4	4	7	2	6	4	8	2	5	4
Participant 66	4	5	4	5	6	4	6	4	5	4	7	4	6	4	6	3	7	3
Participant 67	3	4	3	5	5	5	8	3	3	3	7	3	7	4	7	2	5	3
Participant 68	5	5	5	4	5	5	6	2	5	3	6	4	8	3	4	2	6	3
Participant 69	2	6	4	5	6	4	6	5	6	3	7	2	4	3	5	5	8	2
Participant 70	6	3	4	5	6	5	5	5	5	4	8	3	5	4	6	3	7	3
Participant 71	3	5	6	3	5	3	3	5	6	5	6	3	5	3	6	3	4	4
Participant 72	5	5	5	5	5	6	6	6	5	5	6	6	4	3	5	3	5	5
Participant 73	5	1	5	1	5	1	5	1	5	5	5	1	5	1	5	1	5	1
Participant 74	1	9	4	4	3	7	5	3	5	9	7	5	5	4	1	3	3	5
Participant 75	2	8	7	7	3	7	4	4	2	8	5	5	4	5	3	8	3	7

	Tarmac		Concrete Road		Slabs Road		Cobblestone		Low Bump Road		Stone on Road		Expansion Joints		Bump Road		Manhole Road		Cats Eyes		Broken Road		Rumble Strips		1cm Metal Bar		Transverse Joints		Broken Concrete		Broken Lane		Country Lane	
	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal	Valence	Arousal
Participant 76	9	1	9	2	7	3	5	7	6	3	6	4	6	3	5	4	4	5	4	5	6	3	6	4	5	3	7	4	6	3	6	3	7	3
Participant 77	9	1	8	3	6	2	3	5	5	4	6	2	5	4	5	4	4	4	4	4	5	4	6	5	5	4	8	3	5	4	6	3	6	3
Participant 78	6	5	6	4	6	5	2	1	4	4	4	4	5	3	4	3	4	4	1	1	5	3	5	5	1	1	5	4	1	3	5	4	4	3
Participant 79	9	1	7	2	3	6	2	3	1	4	2	5	4	4	3	4	2	2	4	3	4	2	2	2	2	4	1	3	1	1	1	3	7	5
Participant 80	9	2	8	5	5	4	6	6	3	6	3	6	3	5	5	5	3	4	5	3	6	3	6	4	3	3	6	4	6	3	7	1	4	7
Participant 81	7	5	3	5	3	5	3	7	3	7	3	5	5	5	5	5	4	7	3	5	9	7	5	5	3	5	5	5	3	7	3	7	3	7
Participant 82	9	1	9	1	7	2	2	5	7	3	6	3	6	4	5	5	5	4	5	5	7	4	3	8	5	3	8	4	4	4	6	2	7	2
Participant 83	9	1	9	1	8	2	5	3	8	2	7	2	7	2	7	3	7	2	6	3	7	3	8	3	7	2	8	2	7	2	8	2	9	1
Participant 84	9	1	9	1	8	1	6	3	6	3	7	3	9	3	6	4	4	4	7	3	7	2	7	5	5	4	8	6	7	2	6	3	7	1
Participant 85	9	1	6	1	5	5	4	5	5	3	4	5	7	3	6	3	4	6	3	7	6	2	4	6	7	4	5	4	4	5	8	2	8	7
Participant 86	9	1	9	1	6	3	3	5	5	3	5	4	5	4	5	3	4	4	4	5	6	3	6	4	5	4	7	4	6	4	6	3	6	3
Participant 87	8	1	9	2	7	3	1	9	6	3	6	4	6	3	4	6	4	5	2	4	5	4	6	4	5	3	6	3	6	4	6	2	7	3
Participant 88	8	3	8	1	8	2	4	5	7	1	7	3	5	4	6	3	4	3	3	4	7	2	7	2	5	5	8	4	8	2	8	2	8	1
Participant 89	8	2	9	1	8	2	4	5	7	2	7	2	8	2	8	2	5	3	4	5	8	3	6	2	5	4	9	4	7	2	8	1	8	3
Participant 90	9	1	9	1	8	2	6	3	7	2	7	3	9	3	6	4	4	4	7	3	8	2	5	3	5	4	8	6	6	3	6	3	8	4
Participant 91	9	1	9	1	7	6	3	7	6	5	4	7	1	9	6	5	6	4	4	5	5	5	6	5	7	3	6	5	6	5	7	2	5	6
Participant 92	7	3	8	2	5	6	1	7	6	3	2	8	4	5	3	7	1	9	5	5	5	5	7	3	7	3	7	4	6	5	6	2	3	7
Participant 93	9	1	8	2	3	6	4	5	7	2	6	4	5	4	1	9	2	6	4	4	5	1	7	4	5	3	7	5	5	4	6	3	5	5
Participant 94	8	1	9	1	7	3	4	7	5	4	6	5	5	5	5	4	3	6	6	3	7	3	8	2	5	3	5	5	5	3	6	3	5	1
Participant 95	9	1	6	1	6	2	2	7	4	4	5	5	4	6	5	4	3	7	7	3	3	7	7	3	5	5	7	4	4	4	8	2	3	5
Participant 96	9	1	9	1	7	2	6	5	6	3	6	4	4	4	3	4	5	5	1	1	3	4	6	6	5	3	8	4	4	3	6	3	7	3
Participant 97	9	1	9	1	8	1	3	8	7	3	5	2	5	6	4	7	2	6	4	3	4	5	5	1	4	4	9	6	5	4	6	3	7	4
Participant 98	8	1	9	1	5	5	3	1	8	2	5	2	5	1	5	3	4	4	4	4	7	2	5	3	5	3	8	6	8	2	5	4	7	3
Participant 99	9	2	8	1	6	3	2	3	6	2	5	5	1	9	7	4	4	6	4	5	3	8	5	5	4	4	9	4	7	2	8	2	7	3
Participant 100	9	1	9	1	6	3	4	6	6	3	5	4	1	8	3	5	4	4	3	5	5	5	5	6	5	4	9	4	3	7	8	2	8	3
Participant 101	9	1	9	1	6	5	3	7	6	3	7	2	6	3	2	3	4	5	5	4	6	2	6	4	3	3	8	7	4	4	6	2	5	4
Participant 102	7	2	9	1	6	5	2	5	5	4	4	4	7	3	5	3	4	6	4	5	2	1	6	5	4	4	6	3	6	4	8	2	6	5
Participant 103	9	1	8	1	6	4	2	7	6	2	4	5	6	3	4	7	4	4	3	6	5	4	7	4	5	4	6	6	7	4	1	3	7	5
Participant 104	9	3	9	1	7	3	1	8	5	4	7	3	6	2	4	7	3	7	3	6	3	3	6	5	7	2	7	7	7	2	3	8	8	2
Participant 105	9	1	9	2	6	3	4	5	7	4	4	6	8	2	4	6	5	4	5	4	4	6	4	7	7	3	4	6	5	5	6	3	9	2
Participant 106	8	1	9	2	7	2	6	4	6	2	7	3	6	4	3	4	4	3	4	7	2	7	6	4	6	2	7	5	8	3	6	3	9	2
Participant 107	8	1	9	2	8	1	3	5	6	4	7	3	4	7	2	3	4	3	3	6	4	3	7	2	6	4	9	7	8	2	8	3	7	2
Participant 108	9	2	9	1	6	4	3	5	7	2	6	3	5	5	5	3	4	5	1	8	4	6	9	1	5	5	6	4	6	5	8	3	9	1
Participant 109	9	1	9	2	6	5	4	4	7	2	4	7	5	3	4	5	1	9	5	2	6	4	7	2	3	7	9	2	7	3	8	3	7	1
Participant 110	7	2	9	1	3	6	3	5	7	1	8	2	4	5	5	5	3	7	3	5	7	4	4	5	5	5	9	6	6	5	7	2	5	1
Participant 111	9	1	8	2	7	2	6	4	8	2	5	4	4	4	4	4	5	3	4	5	5	4	6	3	3	4	6	3	7	4	5	4	6	4
Participant 112	9	2	9	1	6	5	6	3	2	5	8	2	9	3	5	3	8	3	4	5	7	3	9	1	5	4	7	5	8	2	5	3	6	3
Participant 113	9	1	7	3	6	4	3	8	5	3	3	8	7	3	4	5	2	9	3	5	6	4	4	5	1	7	7	3	3	7	6	3	7	6
Participant 114	9	1	9	2	7	2	3	5	2	9	6	3	7	3	7	3	6	4	7	3	5	5	7	4	7	3	9	4	7	3	7	4	6	3
Participant 115	9	2	9	1	6	3	2	7	7	2	5	4	3	6	4	7	5	4	4	5	7	2	6	6	2	6	7	3	6	5	7	2	7	2
Participant 116	9	1	8	2	7	3	4	7	6	4	4	6	5	4	5	4	3	7	3	5	5	5	3	6	3	6	7	3	5	4	5	3	8	3
Participant 117	8	2	7	5	4	2	3	2	5	4	4	3	5	5	5	3	2	1	5	5	4	6	7	5	5	5	6	2	2	3	5	4	7	3
Participant 118	7	7	8	4	3	3	2	4	4	3	3	4	3	3	4	4	2	3	5	4	5	4	4	4	3	3	4	3	2	4	5	3	4	5
Participant 119	8	5	9	1	6	3	2	9	2	3	5	4	3	7	4	7	5	4	4	3	2	5	6	8	2	7	7	2	3	5	2	3	3	3
Participant 120	6	6	9	5	7	3	4	3	1	6	6	3	7	4	6	4	4	4	4	5	4	5	6	3	7	4	8	5	6	3	5	1	5	4
Participant 121	9	3	8	1	6	1	6	2	7	4	7	3	7	2	6	3	5	3	3	5	5	2	6	2	6	2	8	4	7	2	6	3	7	4
Participant 122	8	2	6	1	6	3	4	2	7	1	5	4	5	1	6	3	4	3	4	4	6	3	8	2	5	4	5	4	6	3	8	2	8	1
Participant 123	5	1	9	1	7	2	3	5	5	3	7	3	6	3	6	4	4	4	5	3	7	2	5	2	6	3	8	6	6	3	5	1	5	3
Participant 124	8	4	9	1	8	2	6	6	5	2	6	3	7	3	8	2	4	3	6	3	5	2	6	2	7	2	9	7	8	2	7	3	8	4
Participant 125	9	1	9	2	7	2	3	5	8	2	7	3	7	3	7	3	6	4	3	9	3	3	7	4	7	3	9	4	7	4	8	3	7	2
Participant 126	9	1	9	1	7	3	4	5	8	2	5	5	3	6	4	7	5	5	3	6	8	3	6	6	2	7	7	3	6	5	8	3	8	2
Participant 127	9	1	9	1	5	4	3	2	6	4	1	8	1	5	4	7	4	7	3	5	8	2	7	2	4	6	8	2	6	4	5	3	8	2
Participant 128	7	5	9	1	7	3	1	8	5	5	5	4	2	5	7	5	3	5	6	3	4	6	4	3	4	4	3	5	5	4	3	6	4	6
Participant 129	9	2	9	1	6	3	6	2	6	4	6	4	6	1	5	3	2	9	3	3	3	5	4	5	8	1	7	2	6	4	5	3	7	3
Participant 130	9	2	9	1	8	3	8	2	6	2	5	5	5	4	7	4	4	6	6	4	3	6	6	5	7	3	5	8	4	6	8	1	7	3
Participant 131	9	2	9	2	6	5	3	8	5	2	7	3	5	7	7	5	6	4	6	4	7	3	5	3	6	2	7	6	5	4	7	2	7	3
Participant 132	7	5	9	1	7	3	4	7	6	4	7	5	7	3	7	4	3	4	4	4	8	2	6	3	6	4	8	7	8	2	5	4	8	3
Participant 133	8	1	9	1	8	1	6	4	7	3	8	3	7	2	8	3	7	3	2	5	6	3	8	2	7	2	9	4	8	2	6	3	7	3
Participant 134	8	1	9	1	4	3	4	5	8	2	5	2	5	1	4	6	1	8	3	6	7	4	1	9	2	6	8	1	3	3	8	2	9	2
Participant 135	1	3	8	2	7	3	3	7	6	2	4	5	5	4	4	5	4	5	5	3	8	2	3	7	6	3	6	4	5	4	4	3	3	5
Participant 136	8	2	7	3	5	3	3	9	4	5	3	5	1	7	3	1	1	8	1	8	6	4	3	5	2	5	7	1	5	3	6	2	5	4
Participant 137	9	2	9	1	7	3	2	6	3	5	7	2	5	3	5	6	2	4	2	7	2	7	7	2	6	4	6	2	8	1	3	8	4	5
Participant 138	7	4	9	1	7	3	3	6	7	4	8	3	6	2	5	4	4	5	3	4	3	5	7	2	7	2	5	6	6	3	7	2	8	2
Participant 139	9	2	8	1	8	1	3	6	6	2	6	5	7	3	5	4	3	5	3	5	7	2	5	3	8	3	5	5	5	3	7	2	8	3
Participant 140	7	3	9	1	7	3	1	7	7	3	5	3	2	5	6	2	5	2	4	5	7	2	5	2	3	4	8	2	6	2	5	3	7	2
Participant 141	9	1	9	1	8	3	1	6	5	3	4	4	4	7	4	6	6	2	4	5	5	3	5	2	4	5	5	3	6	2	5	2	8	1
Participant 142	8	1	8	2	7	2	4	3	5	3	6	3	6	3	5	3	5	2	2	6	3	4	6	2	6	2	7	7	5	4	7	3	8	4
Participant 143	9	1	6	4	3	3	3	7	7	2	4	7	3	8	5	5	2	7	2	6	4	5	4	5	5	6	5	6	3	7	7	2	7	3
Participant 144	8	3	9	1	8	1	3	5	4	7	7	3	6	3	6	4	4	3	5	3	7	2	7	5	7	3	8	6	6	2	5	7	4	5
Participant 145	8	2	9	1	6	2	5	4	6	2	7	3	5	3	7	4	3	5	4	7	3	8	6	3	6	2	7	6	8	3	7	2	7	1
Participant 146	9	1	8	1	6	1	6	2	7	2	7	2	5	2	6	3	5	3	3	4	8	2	6	2	6	2	8	4	7	2	8	1	8	3
Participant 147	9	1	9	1	8	3	1	9	7	1	8	3	2	7	7	3	3	9	6	3	8	3	6	5	7	2	8	4	7	3	6	5	3	7
Participant 148	8	1	9	2	8	2	4	5	8	2	8	2	7	3	7	2	4	4	5	2	7	2	8	3	8	2	7	6	8	4	8	2	8	2
Participant 149	9	1	7	6	4	2	4	2	8	2	4	2	6	2	5	3	5	3	6	4	6	3	5	4	5	3	4	3	5	4	8	3	9	2
Participant 150	9	2	9	2	8	3	5	6	5	2	7	5	7	4	7	5	4	6	4	5	7	3	7	3	7	4	8	6	5	4	6	2	3	4

Perception Enhancement Systems Research Group

Consent to test of Human Emotional Perception

Brunel UNIVERSITY LONDON
School of Engineering and Design

Please carefully read the information below which summarises the experiment that you are about to perform. Please tick appropriate box indicate your agreement to participate by providing your signature and the date at the bottom.

The purpose of this experiment is to identify the emotional experience human's associate to vehicle vibration in different types of road surfaces. You are asked to take a survey based on your experienced feelings detected through vibrations, using the specially designed simulator you will experience various steering wheel vibrational stimuli similar to actual car vibrations. The laboratory equipment has been adjusted in accordance with the health and safety guidelines specified by *British Standard 7085 Safety aspects of experiments in which people are exposed to mechanical vibration*.

It is important that you keep in mind to express your emotional feelings rather than rating the actual vibrational stimuli.
The experiment will last approximately 30 minutes, in which time you will be exposed to a set of 19 various road type stimuli with pictures of the road surface on the screen in front. Each vibrational stimuli will be displayed three times in random order, where between each signal you will be asked to rate your experienced emotional response. All information will be used for statistical analyses only and will remain strictly confidential.

	Please tick appropriate box	
	YES	NO
Have you read the Research Participant Information Sheet?	☐	☐
Have you had an opportunity to ask questions and discuss this study?	☐	☐
Have you received satisfactory answers to all your questions?	☐	☐
Do you understand that you will not be referred to by name in any report concerning the study?	☐	☐
Do you understand that you are free to withdraw from the study:		
- at any time?	☐	☐
- without having to give a reason for withdrawing?	☐	☐

I agree to participate in the vibration perception experiment which has just been described to me both verbally and in writing.

Signature: ___________________________ Date : _____/_____/ 2011

Experimenter's detail: Mr Arber Shabani, Researcher.
Perception Enhancement Systems Research Group, School of Engineering and Design, Brunel University.
telephone: 07999469500 e-mail: im10aas1@brunel.ac.uk

Test Participant Information Form

Section A – Personal Information

Full Name: ____________________ Gender: Male ☐ Female ☐

Weight: ________________________ Height: ______________________________

Age: _____________________YEARS Driving Experience: _______________YEARS

How often do you drive: ____

What type of vehicle do you normally drive:

Car ☐ Van ☐ MPV ☐ Truck/Bus ☐ 4x4/SUV ☐

Are you often exposed to vibrations, or do you regularly use vibration-producing tools as part of work or hobbies (i.e. tractors, drills)?

Yes ☐ No ☐

*If Yes, please specify:*____

Do you have any physical condition which you feel may affect your vibration test responses?

Yes ☐ *No* ☐

*If Yes, please specify:*____

Did you consume alcohol or coffee in the last hour before the experiment?

Yes ☐ *No* ☐

*If Yes, please specify:*____

The Perception Enhancement Systems research group would greatly appreciate your participation in future research projects, please provide your contact details and we will inform you of upcoming studies:

Email address: ____

Appendix 4

Participant Name →	Part. 1		Part. 2		Part. 3		Part. 4		Part. 5		Part. 6		Part. 7		Part. 8		Part. 9		Part. 10	
Road Signal Name ↓	Valance	Arousal	Valance	Arousal	Valance	Arousal	Valance	Arousal	Valance	Arousal	Valance	Arousal	Valance	Arousal	Valance	Arousal	Valance	Arousal	Valance	Arousal
1- Tarmac	8	1	9	1	9	1	9	1	9	1	8	2	9	1	9	1	9	1	9	1
2- Harsh	5	3	7	2	6	4	6	3	7	1	2	7	7	5	8	2	4	7	6	5
3- Slabs	7	2	9	1	8	2	9	1	8	1	8	2	8	2	9	1	6	3	8	3
4- Bump	7	4	7	1	4	7	5	4	6	3	2	4	7	3	7	3	3	9	4	6
5- Country Lane	6	5	6	4	3	8	2	6	7	3	2	8	8	2	6	3	1	9	2	8
6- Impact	7	3	6	3	4	5	6	3	7	2	3	7	9	2	8	1	5	6	7	4
7- Concrete	9	1	9	1	9	1	9	3	9	1	9	1	9	1	9	1	9	1	9	1
8- Strips	6	3	7	2	5	6	3	6	7	2	8	2	9	1	5	3	1	7	5	6
9- Low Bump	9	2	8	1	7	2	6	4	8	3	8	2	9	1	9	1	6	4	7	2
10- Bcon	4	4	6	3	4	5	1	8	5	3	2	7	8	2	7	2	5	5	3	8
11- Joints	6	5	6	3	3	5	5	4	5	3	3	4	9	2	6	2	6	3	4	7
12- B Lane	4	5	5	3	2	6	1	9	3	5	1	8	8	2	4	4	1	8	2	9
13- Catr_ux	3	6	5	4	2	7	1	8	1	5	1	9	7	3	2	5	3	6	1	8
14- City St	6	4	7	3	3	8	3	5	5	5	5	5	9	2	4	6	6	5	4	7
15- Manhole	7	4	8	2	5	4	6	4	6	4	6	3	9	1	6	2	7	4	6	5
16- Cobbles	6	3	8	1	6	3	8	2	8	1	6	2	9	1	8	1	9	1	8	2
17- Cat_60	6	4	7	2	4	6	4	5	3	5	3	6	9	1	6	3	6	5	4	7
18- Brok	7	3	7	3	4	7	1	8	6	5	2	3	9	3	7	3	4	6	5	6
19- Low Bump	8	1	8	2	6	4	8	3	7	2	8	2	9	2	9	1	6	5	8	3
20- Bcon	5	6	6	3	2	8	1	8	2	5	2	8	8	2	5	4	3	8	3	8
21- Catr_ux	4	6	6	3	1	8	1	9	1	6	1	7	5	6	2	5	1	9	2	9
22- B Lane	4	4	6	3	2	8	1	7	3	6	1	4	7	3	3	4	4	6	2	8
23- Strips80	5	3	7	2	3	7	4	5	4	5	3	4	8	3	6	3	6	5	4	6
24- Concrete	8	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1
25- Impacts	8	2	7	2	6	3	5	3	5	3	4	4	9	2	8	1	7	3	7	4
26- Brok	7	2	7	3	5	6	4	8	5	6	6	3	9	1	8	1	5	6	6	5
27- Harsh	7	3	6	3	3	8	2	9	3	4	3	7	8	3	7	2	3	7	4	7
28- Country Lane	7	3	6	3	1	9	1	9	2	7	1	8	6	2	3	5	1	9	1	8
29- Bump	7	2	7	3	5	6	3	8	5	3	6	3	8	2	5	3	4	6	3	8
30- Slabs	8	2	9	1	8	1	9	1	9	1	9	2	9	1	9	1	9	1	9	1
31- Cat_60	6	3	7	2	3	7	4	4	3	4	7	2	9	2	8	2	3	6	5	6
32- Cobbles	7	2	7	2	6	2	8	1	8	2	8	2	9	4	9	1	8	2	8	2
33- Joints	6	3	6	3	5	3	1	5	5	5	2	7	6	3	8	2	4	5	6	5
34- Tarmac	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1
35- Manhole	7	4	7	2	3	5	2	6	7	5	3	6	7	3	7	2	3	4	5	6
36- City St	6	4	7	3	2	7	2	9	5	5	4	4	6	3	7	3	2	8	4	7
37- Brok	7	2	6	3	3	6	2	9	6	4	4	4	7	2	8	3	6	4	4	6
38- Cat_60	6	4	7	3	3	6	1	7	5	3	8	2	9	1	6	2	5	6	5	6
39- Cobbles	8	1	7	2	6	3	8	1	8	2	8	2	9	1	9	1	8	2	8	2
40- Manhole	6	3	7	2	4	6	2	9	6	3	3	7	7	2	5	3	5	6	6	5
41- City St	5	4	6	2	2	8	1	9	5	4	4	4	8	2	7	2	3	7	5	6
42- Catr_ux	5	4	6	3	1	7	1	9	2	5	2	8	7	3	4	4	2	8	2	9
43- B Lane	7	4	7	3	1	7	1	8	3	6	3	7	7	3	3	4	2	8	2	9
44- Joints	7	2	7	3	5	4	3	7	6	4	4	6	8	2	8	1	4	6	5	6
45- Bcon	5	4	6	3	3	6	1	7	4	4	4	4	8	2	5	3	3	5	4	7
46- Low Bump	9	2	8	2	6	3	6	4	8	1	7	2	9	1	9	1	8	4	8	1
47- Strips	7	3	7	3	6	3	2	9	7	3	4	5	9	3	6	3	4	7	6	5
48- Concrete	9	1	9	1	9	1	9	1	9	1	9	1	9	4	9	1	9	1	9	1
49- Impact	6	3	7	3	5	3	6	2	5	3	7	2	9	2	8	1	4	5	7	4
50- Country Lane	5	5	5	4	1	8	1	9	3	5	2	8	8	2	5	3	1	9	2	9
51- Bump	7	3	6	3	2	7	1	8	5	3	3	7	8	2	4	3	4	7	4	7
52- Slabs	8	2	8	2	7	2	8	1	8	1	8	1	9	4	9	1	8	2	9	2
53- Harsh	7	4	6	3	5	4	2	7	4	4	3	4	9	2	5	3	4	6	5	6
54- Tarmac	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1

Participant Name →	Part. 11		Part. 12		Part. 13		Part. 14		Part. 15		Part. 16		Part. 17		Part. 18		Part. 19		Part. 20	
Road Signal Name ↓	Valance	Arousal	Valance	Arousal	Valance	Arousal	Valance	Arousal	Valance	Arousal	Valance	Arousal	Valance	Arousal	Valance	Arousal	Valance	Arousal	Valance	Arousal
1- Tarmac	9	1	9	1	7	1	9	1	4	1	9	1	9	1	9	1	8	2	7	1
2- Harsh	7	2	7	3	6	2	5	2	7	1	5	5	4	5	7	3	6	5	4	2
3- Slabs	9	1	8	3	8	2	8	2	7	1	7	3	9	1	9	1	8	2	4	3
4- Bump	7	2	6	3	5	5	3	3	6	4	5	6	4	7	6	4	5	4	4	3
5- Country Lane	7	3	7	3	5	7	1	4	8	4	5	7	2	8	5	6	6	5	4	3
6- Impact	8	2	7	2	7	2	8	1	6	2	7	3	5	4	6	4	8	2	6	3
7- Concrete	9	1	8	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1	8	2
8- Strips	7	2	8	2	6	3	2	2	6	2	6	4	5	6	7	2	7	3	4	3
9- Low Bump	8	2	9	1	9	1	5	2	8	1	8	2	7	3	9	1	9	1	5	2
10- Bcon	7	2	7	3	7	4	2	3	3	3	6	4	5	4	6	4	6	3	4	2
11- Joints	7	2	6	2	7	2	7	2	5	3	5	6	7	4	7	3	7	3	6	2
12- B Lane	6	2	6	3	5	4	1	3	3	5	4	6	4	8	6	4	7	4	3	4
13- Catr_ux	5	2	6	2	4	3	3	2	4	5	4	6	2	7	5	4	5	4	2	2
14- City St	5	2	7	2	6	2	4	2	9	1	6	4	4	7	9	1	6	3	7	2
15- Manhole	6	2	7	2	8	1	7	1	8	2	7	2	4	5	7	3	6	3	4	2
16- Cobbles	8	1	9	1	8	3	7	1	9	1	8	2	8	2	9	1	8	1	4	3
17- Cat_60	6	1	8	2	6	2	7	1	3	4	6	4	4	5	7	3	8	2	3	2
18- Brok	6	2	7	2	4	4	7	1	7	2	5	5	5	4	7	4	7	3	5	2
19- Low Bump	8	1	8	1	6	2	9	1	9	1	8	1	6	4	9	1	8	1	6	2
20- Bcon	6	2	6	2	6	3	2	2	5	3	6	4	3	7	7	3	5	5	4	3
21- Catr_ux	4	3	5	3	4	5	2	2	3	3	5	5	2	8	6	4	5	5	4	2
22- B Lane	4	3	6	3	4	5	1	4	3	5	4	6	2	8	7	4	7	4	3	3
23- Strips80	5	2	6	3	4	4	7	1	4	4	5	5	4	6	7	3	7	3	3	3
24- Concrete	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1	8	2
25- Impacts	7	1	7	2	6	3	8	1	6	1	7	3	6	3	7	2	7	4	5	4
26- Brok	6	2	7	2	6	3	6	2	6	1	6	4	5	5	7	3	7	4	4	4
27- Harsh	6	2	6	3	6	2	7	2	4	4	4	5	7	3	7	4	6	4	2	3
28- Country Lane	3	2	6	4	5	5	2	3	7	1	3	6	1	9	5	4	6	5	5	3
29- Bump	6	2	6	3	4	3	5	3	7	2	5	4	3	8	7	2	6	4	4	3
30- Slabs	9	1	8	2	7	1	9	1	9	1	8	2	9	1	9	1	9	1	4	2
31- Cat_60	4	3	8	2	5	2	6	2	3	5	6	3	7	3	7	2	7	4	5	2
32- Cobbles	8	1	9	1	7	2	9	1	9	1	7	3	8	2	8	2	8	2	4	3
33- Joints	6	2	7	2	6	2	4	2	6	5	5	6	7	2	6	2	7	4	5	2
34- Tarmac	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1	8	1
35- Manhole	7	2	7	3	5	3	5	2	7	2	6	4	5	5	6	3	7	3	3	3
36- City St	5	2	7	2	7	2	6	2	9	1	6	4	3	8	8	2	6	5	4	3
37- Brok	6	2	8	2	5	3	4	1	8	1	7	3	5	7	6	3	7	4	5	3
38- Cat_60	5	2	8	2	7	1	2	1	3	5	7	3	5	4	7	3	6	5	5	2
39- Cobbles	8	1	9	1	7	1	9	1	9	1	8	2	8	2	8	2	8	2	4	3
40- Manhole	6	2	7	2	5	3	5	2	8	2	6	4	5	6	6	3	6	4	3	3
41- City St	3	3	7	3	6	2	5	2	9	1	5	4	3	8	7	2	7	5	4	2
42- Catr_ux	3	3	5	3	5	4	2	2	2	5	4	5	2	6	5	3	5	6	3	3
43- B Lane	3	3	6	3	5	2	2	3	4	6	4	5	2	7	5	3	5	4	3	3
44- Joints	7	2	7	2	7	2	5	3	5	3	6	4	5	6	7	2	7	3	6	2
45- Bcon	5	2	6	3	5	3	3	2	4	3	7	3	4	6	7	3	5	5	4	3
46- Low Bump	8	1	8	2	7	1	8	1	9	1	8	2	6	3	8	2	9	1	5	2
47- Strips	6	2	7	2	4	3	7	1	6	5	6	3	6	4	7	2	7	4	3	3
48- Concrete	9	1	9	1	8	1	9	1	9	1	9	1	9	1	9	1	8	2	7	2
49- Impact	6	2	8	2	5	3	7	1	7	1	7	3	4	4	7	2	7	4	6	2
50- Country Lane	3	3	5	4	6	2	2	3	7	1	5	6	2	9	5	3	5	6	5	3
51- Bump	6	2	5	4	4	2	5	2	8	4	6	4	3	6	6	3	6	5	4	3
52- Slabs	9	1	8	1	9	1	9	1	9	1	8	2	7	2	8	2	9	1	5	1
53- Harsh	7	1	7	3	6	1	4	3	6	4	6	4	6	4	5	3	7	2	3	3
54- Tarmac	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1

Participant Name →	Part. 21		Part. 22		Part. 23		Part. 24		Part. 25		Part. 26		Part. 27		Part. 28		Part. 29		Part. 30	
Road Signal Name ↓	Valance	Arousal	Valance	Arousal	Valance	Arousal	Valance	Arousal	Valance	Arousal	Valance	Arousal	Valance	Arousal	Valance	Arousal	Valance	Arousal	Valance	Arousal
1- Tarmac	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1
2- Harsh	8	2	6	5	8	5	8	1	2	8	6	1	5	3	4	5	8	1	7	3
3- Slabs	9	1	8	1	9	1	9	1	7	2	9	1	8	2	6	3	9	1	8	1
4- Bump	8	2	4	6	6	6	8	1	5	5	6	2	4	3	4	4	7	4	6	3
5- Country Lane	7	2	8	8	7	6	7	1	4	5	7	1	5	4	3	5	5	4	5	4
6- Impact	8	2	7	3	7	2	8	1	5	3	5	1	4	4	4	4	8	3	6	3
7- Concrete	9	1	9	1	9	1	9	1	8	2	9	1	9	1	6	3	9	1	9	1
8- Strips	7	3	5	6	5	7	9	1	5	5	4	2	6	3	5	4	6	4	6	3
9- Low Bump	9	1	8	3	8	2	9	1	6	2	6	1	6	2	6	4	8	2	8	2
10- Bcon	6	3	5	4	4	7	7	2	4	4	7	1	3	3	4	4	6	3	7	3
11- Joints	6	2	7	4	8	2	7	2	4	4	6	2	6	5	4	4	7	3	6	3
12- B Lane	7	3	2	5	7	4	6	2	3	6	8	1	5	5	3	6	6	4	6	3
13- Catr_ux	7	3	2	8	6	5	6	2	1	7	7	1	2	6	5	5	5	5	4	4
14- City St	8	2	7	7	5	4	7	2	3	6	7	1	6	3	5	3	6	3	6	3
15- Manhole	7	2	8	2	7	3	8	1	4	3	7	1	7	3	6	3	7	3	7	3
16- Cobbles	9	1	5	4	9	1	8	1	5	4	7	1	8	1	6	3	8	2	8	2
17- Cat_60	8	2	4	7	7	3	7	2	2	7	6	1	7	3	5	2	7	3	7	2
18- Brok	7	2	9	8	5	6	7	2	2	6	5	1	7	5	4	4	7	3	6	3
19- Low Bump	9	1	7	3	9	1	8	1	5	3	9	1	7	3	5	4	9	1	8	2
20- Bcon	6	3	3	5	7	3	7	2	4	4	7	2	4	5	2	5	7	2	5	3
21- Catr_ux	6	2	2	8	6	4	6	2	1	8	5	1	3	8	1	6	6	4	5	3
22- B Lane	7	2	1	6	4	5	5	2	5	4	5	1	5	5	1	8	7	3	6	3
23- Strips80	8	2	5	5	7	4	8	2	3	6	6	2	6	4	4	5	7	3	6	3
24- Concrete	9	1	9	1	9	1	9	1	3	3	9	1	9	1	7	2	9	1	9	1
25- Impacts	8	1	7	2	6	4	8	2	3	6	5	2	6	3	6	4	8	2	6	3
26- Brok	8	2	9	7	6	3	7	2	2	6	7	2	5	4	4	5	7	3	5	3
27- Harsh	7	2	6	3	4	3	6	1	2	6	6	2	4	3	4	4	6	4	6	3
28- Country Lane	5	4	9	9	4	4	5	2	2	7	5	1	3	5	3	4	6	4	4	4
29- Bump	6	3	2	4	8	3	7	1	2	9	6	2	4	4	3	5	7	4	5	3
30- Slabs	9	1	9	1	9	1	9	1	5	3	9	1	8	1	6	3	9	1	9	1
31- Cat_60	8	2	2	8	7	3	8	3	2	7	7	1	7	3	5	4	7	3	7	2
32- Cobbles	9	1	8	5	9	2	8	1	5	4	7	1	8	1	7	2	9	1	8	2
33- Joints	6	2	7	4	6	3	5	2	2	8	7	1	3	4	5	4	7	3	6	3
34- Tarmac	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1
35- Manhole	8	2	8	2	6	4	6	2	3	7	7	2	7	2	5	5	8	2	6	3
36- City St	7	2	6	3	5	5	6	2	3	7	5	2	6	4	2	6	7	3	6	3
37- Brok	6	3	9	7	6	4	7	2	2	7	8	1	6	5	3	6	7	3	5	4
38- Cat_60	8	2	3	7	7	2	8	1	2	8	7	1	7	3	4	4	8	2	6	3
39- Cobbles	9	1	8	6	9	1	8	1	4	4	7	1	8	1	6	3	9	1	8	2
40- Manhole	9	2	7	2	7	3	7	2	3	5	6	1	7	2	5	4	8	2	6	3
41- City St	6	3	8	4	5	5	7	2	2	7	6	1	4	4	3	6	7	3	5	4
42- Catr_ux	6	4	3	5	4	5	6	3	1	9	5	2	2	7	1	7	5	5	5	4
43- B Lane	7	3	2	7	4	6	6	2	1	8	6	1	2	5	3	5	6	4	5	4
44- Joints	8	2	6	2	8	2	6	3	3	4	6	1	3	4	4	4	7	3	6	3
45- Bcon	8	2	5	4	7	3	6	2	3	6	7	1	4	4	4	6	8	3	6	3
46- Low Bump	9	1	8	2	9	1	8	1	4	6	6	1	7	2	5	4	8	1	7	3
47- Strips	7	1	3	3	6	4	7	2	2	6	7	1	4	3	4	7	7	2	6	3
48- Concrete	9	1	9	1	9	1	9	1	8	2	9	1	8	1	7	3	8	1	9	1
49- Impact	7	2	7	1	8	2	7	3	4	4	8	1	6	3	5	4	6	3	6	3
50- Country Lane	5	2	9	9	4	6	5	3	2	7	5	1	4	5	2	9	6	4	4	4
51- Bump	8	2	1	6	4	4	6	2	4	7	7	1	4	4	3	6	7	3	5	4
52- Slabs	9	1	7	1	9	1	8	1	7	2	9	1	7	2	6	4	8	2	8	1
53- Harsh	7	1	1	5	7	3	6	2	1	8	5	1	6	3	5	4	6	4	6	3
54- Tarmac	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1	9	1

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School of Engineering and Design

Consent Form to Identify the Driver Vocabulary of Automotive Vibration Feedback

I. Introduction

Please carefully read the information below summarising the field study that you are about to participate in, (if you choose to do so) please fill in the following form and indicate your agreement to participate in the study by providing your signature and the date at the bottom of the consent certificate.

The aim of this field study is to gather the driver vocabulary used to describe their perceptions and felt experiences of the automotive vibration feedback. You will be asked to provide as many attributes / descriptors, which you would use to describe the automotive vibration feedback, felt while driving over various road surface types. This will in turn provide a better understanding of the semantic spaces of automotive vibration stimuli and the quality dimensions related to this driver feedback, which will provide valuable insights to automotive manufacturers for designing automobiles with imbedded vibration quality characteristics.

II. About the Field-Study

If you decide to join the field study, then we will ask you to drive through a specified route, which will include 8 various driving scenarios with different road surface types. After each of the 8 events you will be asked a set of two questions regarding your felt experience of the vibration feedback perceived during that event. The study will last approximately 55 minutes, which is also dependent on the traffic density.

The first questions will help to gather the verbal attributes, which you use to describe your perception of the automotive feedback in order to build a semantic vocabulary used for various driving events. And the second question will try to identify additional attributes that you may be able to think which contributed to your perception of that felt vibration.

You are required to drive carefully and in an ordinary fashion, without letting the verbal study to affect your actual driving task, as safety is crucial. If necessary you can pause the study for a break if you need to take time to respond to the questions.

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For this study it would be preferred that you drive your own automobile during this driving task, as the aim is to gather peoples wider expressions without limiting the responses to one set automobile. If using a personal automobile is not possible, one can be supplied provided that the all the necessary legal requirements are fulfilled (license, insurance, etc).

Please be advised that we shall try to minimise any possible risks and If you did feel that there was any stress involved you can stop at any time. Also the information gathered from this field study will be used for statistical analysis only and will remain strictly confidential and that you can withdraw from the study at any point just indicate that to the researcher.

III. Certificate of Consent

Identifying the Driver Vocabulary of Automotive Vibration Feedback

Please tick all the appropriate boxes

	YES	NO
I have read the Consent Form information sheets…………………………	☐	☐
I have had the opportunity to ask questions and discuss this study……	☐	☐
I have received satisfactory answers to all my questions………………..	☐	☐
I understand that my details will be kept confidential……………………..	☐	☐
I understand that I may withdraw from this study at any time…………..….	☐	☐

I ________________________ (print name here) give my consent to participate in this filed study and use my responses for research purposes only.

Signature: ____________________________

Date: __________/__________/__________

PER PERCEPTION ENHANCEMENT RESEARCH

HCDI Human Centred Design Institute

Brunel UNIVERSITY LONDON
School of Engineering and Design

IV. Participant Information

Full Name: ____________________________ Gender: Male ☐ Female ☐

Weight: ______________________________ Height: ______________________________

Age: ____________________________YEARS Occupation: __________________________

Driving Experience: _______________YEARS Miles per Week: ___________________MILES

Nationality: ____________________________ Country of Origin: _____________________

Are you often exposed to vibrations, or do you regularly use vibration-producing tools as part of work or personal interest (i.e. tractors, drills, etc.)? YES ☐ NO ☐

If Yes, please specify: ____

Do you have any physical condition, which you feel may affect your vibration test responses?

YES ☐ NO ☐ If Yes, please specify: ___________________________

Did you consume alcohol or coffee in the last two hours before the study?

YES ☐ NO ☐ If Yes, please specify: ___________________________

What Type of vehicle do you regularly drive?

Car ☐ Van ☐ MPV ☐ Truck/Bus ☐ 4x4/SUV ☐

Vehicle Make & Model: _________________ Year of Registration: __________________

What type of driver do you consider yourself as?

Slow Driver ☐ Usually Slow ☐ Usually Fast ☐ Speedy Driver ☐

V. Contact Details

For any further questions on this field study or to find out the progress of the research project please contact: Arber Shabani / arber.shabani@brunel.ac.uk / Mob:07999 469 500

Supervised by : Marco Ajovalasit (marco.ajovalasit@brunel.ac.uk) & Joseph Giacomin (joseph.giacomin@brunel.ac.uk)

Thank you for your Participation

This project has been approved by the ethics committee of the School of Engineering and Design, Brunel University.

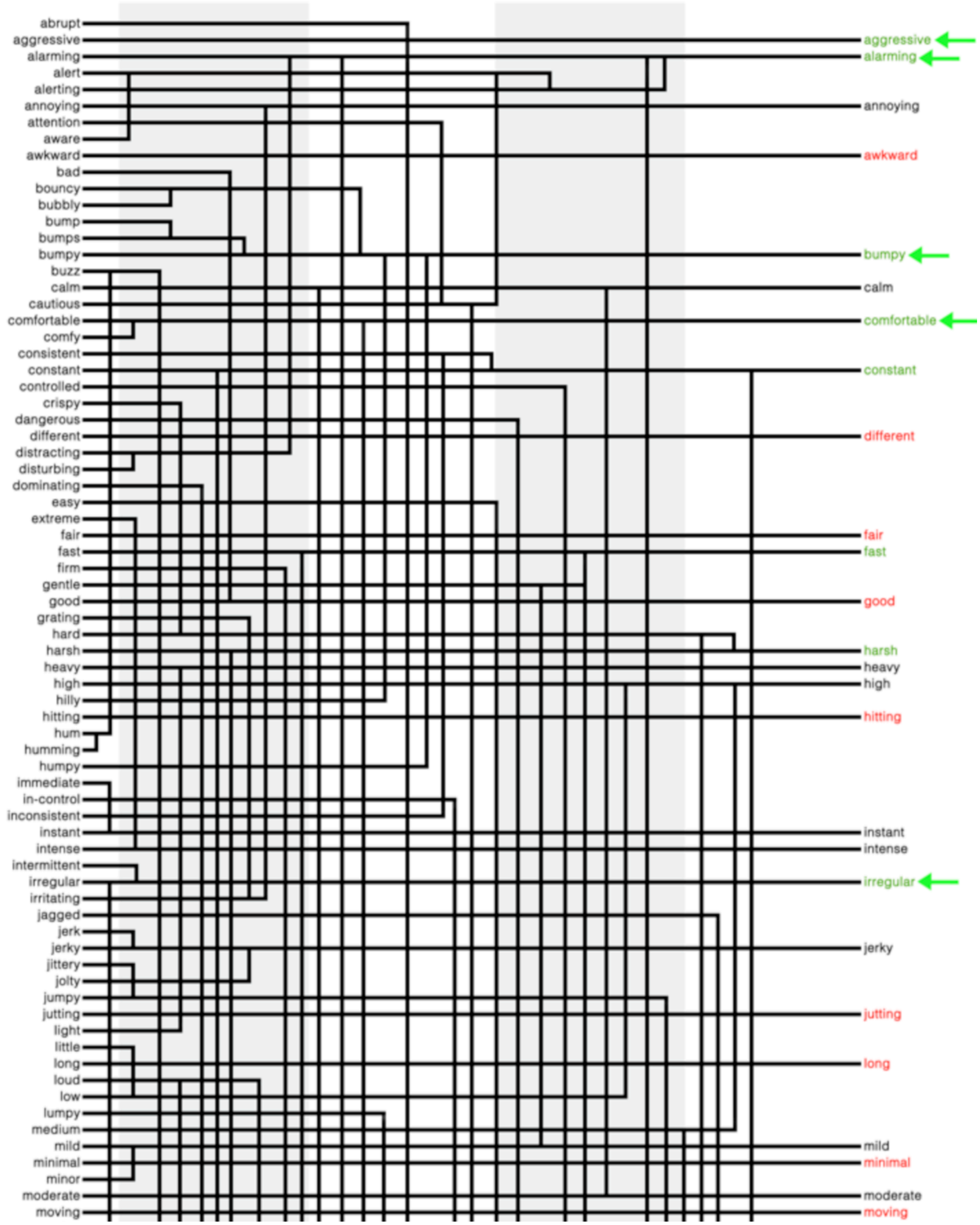
PER PERCEPTION ENHANCEMENT RESEARCH — HCDI Human Centred Design Institute

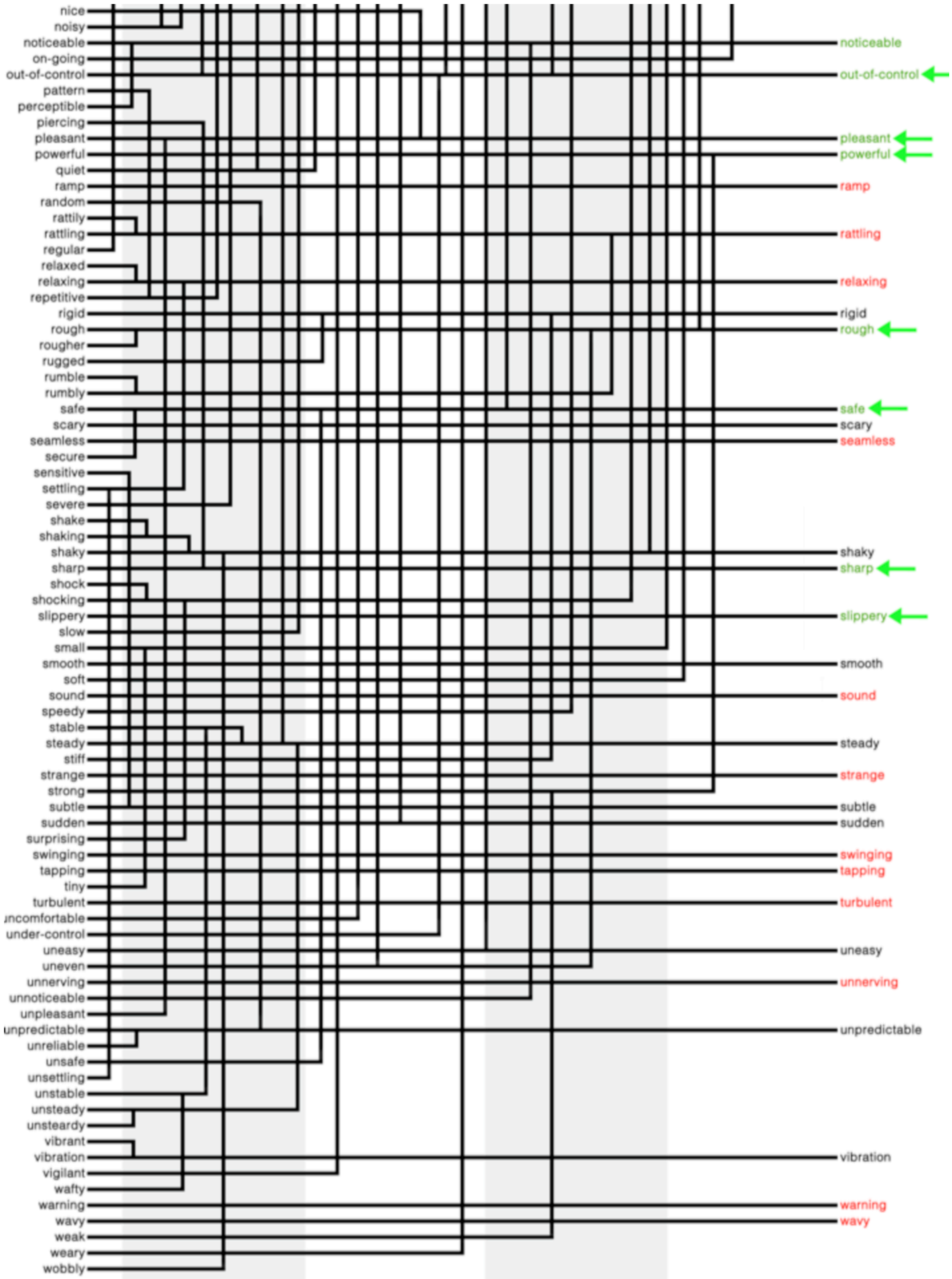
Appendix 6

	Road Event 1	Other Words	Road Event 2	Other Words	Road Event 3	Other Words	Road Event 4	Other Words	Road Event 5	Other Words	Road Event 6	Other Words	Road Event 7	Other Words	Road Event 8	Other Words
Road Type	Small rubber bump		Broken road		Country road		Tarmac road		Cats eyes		Rumble strips		Cobblestone road		Large bump	
Participant 1	not heavy, moderate	fair vibrations	smooth, not rough, uneven		harsh, rough	uneasy, uneven	minor vibration	smooth	harsh, uneasy, uneven,		smooth, constant, alerting		bumpy, uneven, rough to moderate		smooth, constant, not too harsh	sudden bump
Participant 2	bumpy, but calm	sharp	uneven, unsteady	uncomfortabl e	bumpy, fast bumps, a little bit shaky	unsteady	soft, calm	pleasant	slightly annoying, small bumps	shaky	loud, a bit shaky	unnerving	shaky, bumpy	turbulent	rumbly, bumpy	jumpy
Participant 3	sharp, fast, jolty		wobbly, unsteardy,	shaky	very bumpy, very shaky,		moderate, smooth	quiet low vibration	very wobbly	shaky	very shaky	uncomfortabl e	very wobbly but vibration not to high		not too bad, slight vibration	a bit shaky
Participant 4	sudden, aggressive	uncomfortabl e, sharp	unpleasant, uncomfortabl e	alerting, annoying	rough, unpleasant	harsh, sharp	uncomfortabl e	unpleasant, irritating	irritating, not too uncomfortabl e, harsh, sudden	alert	alerting, slightly uncomfortabl e		jolty, unpleasant,	alerting, shaky	unpleasant, sharp	harsh
Participant 5	slow, uncomfortabl e	weak	shaky, uneven, harsh	uncomfortabl e	wavy	bumpy	small vibration, with small bumps	under control	alarming,	aware	loud, small vibrations, alarming, warning sign	cautious, shaky	very shaky, noisy		uncomfortabl e, harsh	
Participant 6	medium vibration		really bumpy, intense	strong, powerful	medium vibration	soft, easy to drive	smooth, small vibration	slight vibration	strong vibration	not too harsh, medium	sharp,	shaky, dominating	strong vibration	uncomfortabl e	medium	not dangerous, mild, safe
Participant 7	uncomfortabl e, annoying		bumpy, uncomfortabl e,		irritating, bumpy		easy, comfortable	more pleasant	scary,	disturbing, uncomfortabl e	noisy, unpleasant	irritating	unpleasant, irritating	vigilant	bumpy	uncomfortabl e
Participant 8	hard, rough	bumpy	very bumpy, very rough, hard to drive on	shaky, bumpy	shaky, powerful	bumpy,	powerful, shaky, bumpy	quiet powerful	very high vibration, very shaky, very powerful	humpy, bumpy	shaky, bumpy, speedy vibrations	alarming	very shaky, bumpy, alerting	very humpy	quiet bumpy, shaky,	humpy
Participant 9	uncomfortabl e, strange	awkward	very bumpy	uncomfortabl e	dangerous, unstable		slightly rough, quiet smooth	a bit uneasy	quiet intense, rough	controlled	on-going, pretty smooth	stable	extremely intense, quiet uncomfortabl e, rough	powerful	pretty soft, not too rough, weak	
Participant 10	rough, uncomfortabl e	not smooth	uncomfortabl e, unreliable, not smooth, rough	unsafe	rough, unsafe, uncomfortabl e	not very smooth	smooth, gentle, soft	in control	alerted me, aware, not to uncomfortabl e	sensitive	very uncomfortabl e, noisy	jumpy	shaky, not good, uncomfortabl e	out of control	sensitive, very smooth, comfortable, not harsh	nice and gentle
Participant 11	soft	smooth, not too harsh	unpleasant, shaky,	rattily	shaking, sudden bumps	wafty, hilly	constant, small sharp bumps	not unpleasant, weak	sharp, sound	alert	not sharp	shaking and tapping, hum	shaky, not steady, rumble, ups and downs	aware of cobblestone	abrupt, had to slow down	softer than expected
Participant 12	bump, jerk		very bumpy		a bit bumpy	shaky	gentle vibration	smooth	minimal jerk, a little bumpy		strong vibration,		quiet severe		smooth bump	
Participant 13	not much vibration	slightly bumpy	small vibration	uncomfortabl e, wobbly	wobbly	not too rough	very smooth	soft vibration, relaxing	not uncomfortabl e, strong	slightly rough and bumpy	scary, constant	shaky, strong vibration	a bit shaky, not very uncomfortabl e or strong		smooth bump	calm, light
Participant 14	quiet smooth	not rigid	uncomfortabl e, quiet rough	rigid	stiff and rough, uncomfortabl e, unstable	bumpy, a bit of jerk	tiny vibration, a bit jumpy, slightly bumpy, subtle, smooth	rougher than expected, bubbly	bumps, very rough, not subtle		heavy vibration, loud buzz, shock	uncomfortabl e, wobbly, rigid, stiff	very bumpy, rigid, bouncy, wobbly		smooth, with a bit of stiff vibration	rigid
Participant 15	steady	a bit high	quiet rough	a bit unpredictable, really jerky	rough, unpredictable, unsteady	stiff	ok vibration, a bit unpredictable and stiff		loud, annoying	a bit rough, jerk	very loud and quiet distracting	shaky	quiet rough and heavy	loud	quiet high, perceptible, not as rough	unpleasant
Participant 16	firm vibration	quiet aggressive	uncomfortabl e	aggressive	comfortable but a bit cautious	you have to be weary	relaxed, slight bumps	minimal vibration	quiet comfortable	very noticeable	aggressive, uncomfortabl e, not a nice experience	repetitive	very uncomfortabl e	unpleasant	pleasant, comfortable	
Participant 17	low vibration	pretty smooth	quiet bumpy	not smooth	jittery	very bumpy	low vibration	not too noticeable	intense	very bumpy	very intense	high and bumpy vibrations	very jittery	bumpy	slightly bumpy	not too smooth
Participant 18	soft vibration	smooth	bumpy, a bit sharp	shaky	not too bumpy, a bit shaky, comfy	sharp	weak vibration, comfy	smooth	shaky, not comfy, strong	not very smooth	not comfy, shaky, powerful, strong		shaky, powerful, strong	not comfy	powerful, big bump, strong	very shaky
Participant 19	quiet harsh	tire shake	not comfortable, out of control	very uncomfortabl e, noisy	bumpy, moving	harsh	very loud, quiet a lot of vibration	uncomfortabl e	very bumpy	uncomfortabl e	very loud and uncomfortabl e		very bumpy, slippery	uncomfortabl e, noisy	quiet rough, loud	not comfortable
Participant 20	slight bump	not too bad	a lot more shaky	rough	quiet rough	fast and powerful vibration	moderate	not to noticeable	large bump	powerful jerk	very distracting	loud	very bumpy	rough	not too bumpy	smoother than expected
Participant 21	bumpy	wobbly	bumpy	wobbly	quiet smooth & gentle		smooth	gentle	bumpy	high bumps with wide gaps	sudden, loud	consistent	lumpy	consistent	very smooth	gentle
Participant 22	instant	abrupt	rugged	uncomfortabl e	bumpy	jagged	humming	constant	piercing, jutting	abrupt	scary, humming, intense	grating	bumpy	jagged	long and hilly	
Participant 23	bumpy	annoying	intense, annoying	unpleasant	slightly intense, a bit scary, not secure	unstable, unpleasant	smooth, calm		grabs my attention, immediate	different, noticeable, distracting	distracting, scary, surprising, slightly shocking		noisy, shaky		annoying	instant, shocking
Participant 24	settling	OK	very wobbly	swinging, quiet rough	OK	a little bumpy	settling	a little vibration, mild	scary	bumpy	annoying	alarming	rattling	a lot of vibration	unsettling	rough
Participant 25	slightly bumpy	moderate	moderate to high vibrations	bumpy	jerky	moderate bumps	calm, smooth	little / weak vibration	annoying	constant	very loud	really annoying, severe	constantly bumpy	very jerky	mild vibration	slight bump
Participant 26	shaky		bumpy	inconsistent	very bumpy		smooth	not much vibration, occasional bump	jerky	consistent	vibrant, intense		vibrating a lot, a lot of bumps	random	felt slight bumps	pretty smooth
Participant 27	heavy vibration	jumpy	quiet rough		mild / moderate vibration	smooth, not harsh	smooth, consistent	occasionally mild vibration	pattern	strong, bumpy	extreme, loud	consistent, annoying, scary	intense, extremely bumpy	jumpy, feel the vibrations individually	smooth and mild vibrations	small vibrations
Participant 28	bumpy		constantly bumpy	shaky	harsh	shaky, strong	smooth	slight shaking	not smooth, a lot of shake	very strong	very harsh	annoying, loud	irregular	bumpy	small bump	slightly shaky
Participant 29	quiet strong	bumpy	very bumpy	unpleasant	uncomfortabl e	jerky	seamless	a bit unnoticeable	very jerky	jittery	noisy, very bumpy	unpleasant	constantly jerky	wobbly	slight jerk	small bump
Participant 30	bumpy, ramp, hitting	strong, harsh	harsh	crispy	comfy, hard, noisy	rough, bumpy, harsh, irregular	noisy, smooth, regular	safe	irregular	intermittent	annoying, alarming, scary, very harsh, strong		shaky, irregular	shaking	irregular, bumpy	uncomfortabl e

Appendix 7

MERGING PROCESS OF GATHERED DESCRIPTORS




nice
noisy
noticeable
on-going
out-of-control
pattern
perceptible
piercing
pleasant
powerful
quiet
ramp
random
rattily
rattling
regular
relaxed
relaxing
repetitive
rigid
rough
rougher
rugged
rumble
rumbly
safe
scary
seamless
secure
sensitive
settling
severe
shake
shaking
shaky
sharp
shock
shocking
slippery
slow
small
smooth
soft
sound
speedy
stable
steady
stiff
strange
strong
subtle
sudden
surprising
swinging
tapping
tiny
turbulent
uncomfortable
under-control
uneasy
uneven
unnerving
unnoticeable
unpleasant
unpredictable
unreliable
unsafe
unsettling
unstable
unsteady
unsteardy
vibrant
vibration
vigilant
wafty
warning
wavy
weak
weary
wobbly
noticeable
out-of-control
pleasant
powerful
ramp
rattling
relaxing
rigid
rough
safe
scary
seamless
shaky
sharp
slippery
smooth
sound
steady
strange
subtle
sudden
swinging
tapping
turbulent
uneasy
unnerving
unpredictable
vibration
warning
wavy

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Consent Form to Measure the Driver Vocabulary of Automotive Vibration Feedback

I. Introduction

Please carefully read the information below summarising the field study that you are about to participate in, (if you choose to do so) please fill in the following form and indicate your agreement to participate in the study by providing your signature and the date at the bottom of the consent certificate.

The aim of this field study is to measure the verbal descriptors used by drivers in order to define the felt steering wheel vibrations. Using the 5-point rating scale, you will be asked to rate each of the descriptive pairs that I read out loud, based on the automotive vibration feedback felt while driving over various road surface types. The results will provide a better understanding of the semantic spaces of different automotive classes and the quality dimensions related to this driver feedback, in turn establishing insights for automotive manufacturers and the vibration quality targets achieved by current automotive classes and the main dimensions used to define automotive vibration quality.

II. About the Field-Study

If you decide to participate in the field study, then you will be given directions to drive through a specified route, which will include 8 various driving scenarios with different road surface types. During each of the 8 events you will be asked to rate the vibration feedback which you feel while driving over that event. The study will last approximately 35-45 minutes, which is also dependent on the traffic density.

Each of the 13 descriptive pairs I read out, need to be rated using the 5 point scale in front of you. For example if I read out 'pleasant and annoying' you need to state whether the steering wheel vibrations feels "extremely pleasant", "moderately pleasant", "neither", "moderately annoying" or "extremely annoying". This test will help measure and map out the semantic space of the various automotive classes tested in this study.

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For this study you are required to drive carefully and in an ordinary fashion, without letting the verbal communication to affect your actual driving task, as safety is crucial. If necessary you can pause the study for a break if you need to take time to respond to the questions. You will need to drive the specific automobile provided for the driving task, as the aim is to gather people's perceptions of vibration feedback stimuli from a selection of automotive classes.

Please be advised that we shall try to minimise any possible risks, and if you did feel in danger at any time you can stop the automobile when it is safe to do so. Also the information gathered from this field study will be used for statistical analysis only and will remain strictly confidential. It is your responsibility to ensure that all of the necessary legal requirements are fulfilled (license, insurance, etc).

III. Certificate of Consent

Identifying the Driver Vocabulary of Automotive Vibration Feedback

Please tick all the appropriate boxes

	YES	NO
I have read the Consent Form information sheets…………………………	☐	☐
I have had the opportunity to ask questions and discuss this study……	☐	☐
I have received satisfactory answers to all my questions………………..	☐	☐
I understand that my details will be kept confidential……………………..	☐	☐
I understand that I may withdraw from this study at any time………..….	☐	☐

I _______________________ (PRINT NAME HERE) give my consent to participate in this filed study and use my responses for research purposes only.

Signature: ____________________________

Date: __________/__________/__________

Brunel UNIVERSITY LONDON
School of Engineering and Design

IV. Participant Information

Full Name: ______________________ Gender: Male ☐ Female ☐

Weight: ______________________ Height: ______________________

Age: ______________________YEARS Occupation: ______________________

Driving Experience: ______________YEARS Miles per Week: ______________MILES

Nationality: ______________________ Country of Origin: ______________________

Are you often exposed to vibrations, or do you regularly use vibration-producing tools as part of work or personal interest (i.e. tractors, drills, etc.)? YES ☐ NO ☐
If Yes, please specify: ______________________________

Do you have any physical condition, which you feel may affect your vibration test responses?
YES ☐ NO ☐ If Yes, please specify: ______________________

Did you consume alcohol or coffee in the last two hours before the study?
YES ☐ NO ☐ If Yes, please specify: ______________________

What Type of vehicle do you regularly drive?
Car ☐ Van ☐ MPV ☐ Truck/Bus ☐ 4x4/SUV ☐

Your Vehicle Model: ________________ Year of Registration: ________________

V. Contact Details

For any further questions on this field study or to find out the progress of the research project please contact: Arber Shabani / arber.shabani@brunel.ac.uk / Mob:07999 469 500
Supervised by : Marco Ajovalasit (marco.ajovalasit@brunel.ac.uk) & Joseph Giacomin (joseph.giacomin@brunel.ac.uk)

Thank you for your Participation

This project has been approved by the ethics committee of the School of Engineering and Design, Brunel University.

Appendix 9

BMW 1 Series

Road Event 1 – Small rubber bump	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	2	4	4	5	4	2	4	2	1	1	2	2	4
Participant 19	2	3	2	4	5	1	4	4	2	4	2	2	2
Participant 18	2	3	4	5	4	2	2	2	1	2	2	4	5
Participant 17	3	2	5	5	3	3	1	3	1	2	1	2	3
Participant 16	2	2	5	3	4	2	2	4	1	2	1	2	2
Participant 15	3	4	2	3	4	1	4	5	1	1	2	2	5
Participant 14	2	2	4	3	4	1	1	5	1	1	1	2	4
Participant 13	2	2	5	5	3	1	1	4	1	1	1	4	5
Participant 12	5	2	5	4	3	3	1	3	1	1	2	2	3
Participant 11	2	2	4	5	4	3	2	3	1	1	2	1	4
Participant 10	2	3	4	5	5	1	3	3	1	1	2	2	4
Participant 9	2	2	4	4	5	1	4	4	2	2	2	2	4
Participant 8	3	4	3	3	5	2	2	5	2	2	4	2	4
Participant 7	5	2	5	5	3	3	1	4	1	2	1	1	3
Participant 6	2	4	2	4	5	1	4	4	2	4	2	2	5
Participant 5	2	2	4	5	5	1	2	2	1	2	2	4	5
Participant 4	4	2	4	5	5	2	4	3	1	1	2	2	4
Participant 3	2	2	5	4	4	2	2	4	1	2	2	2	2
Participant 2	2	1	5	5	5	1	1	1	1	1	1	2	4
Participant 1	5	4	2	4	5	2	4	4	2	2	1	2	3

Road Event 2 – Broken road	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	4	1	5	5	2	4	1	2	1	1	1	5	2
Participant 19	4	2	4	5	4	4	2	2	1	2	1	4	2
Participant 18	4	4	4	5	5	2	4	2	1	1	1	5	5
Participant 17	5	1	4	5	1	5	1	2	1	1	1	5	2
Participant 16	4	1	4	5	4	4	2	1	1	2	1	5	3
Participant 15	4	2	4	5	4	2	2	5	1	2	1	4	4
Participant 14	5	1	4	5	1	3	1	2	1	1	1	5	3
Participant 13	4	3	4	5	5	3	1	2	1	1	1	4	5
Participant 12	5	1	4	5	5	4	2	2	1	2	1	4	3
Participant 11	4	3	3	4	4	3	2	2	2	1	2	4	4
Participant 10	4	4	4	5	4	1	4	2	1	2	1	5	3
Participant 9	2	2	4	5	5	2	2	4	1	2	2	5	2
Participant 8	5	2	4	5	4	4	2	3	1	1	1	5	3
Participant 7	5	1	5	5	1	5	1	2	1	1	1	5	3
Participant 6	4	1	4	5	4	4	2	2	1	2	1	4	4
Participant 5	5	4	4	5	5	1	4	2	1	1	1	5	5
Participant 4	5	1	5	5	2	4	1	2	1	1	1	5	1
Participant 3	5	1	4	4	4	4	2	1	1	2	1	5	3
Participant 2	5	1	4	5	4	1	1	1	1	1	1	5	4
Participant 1	4	3	3	4	4	4	1	2	1	2	1	4	4

Road Event 3 – Country road	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	1	2	3	2	4	2	4	4	2	3	2	4	4
Participant 19	2	4	2	2	5	2	4	5	5	4	4	2	4
Participant 18	2	4	2	4	5	1	4	2	3	4	2	4	5
Participant 17	1	2	3	4	5	3	2	2	2	2	2	3	4
Participant 16	2	4	2	2	5	2	2	4	4	2	4	3	4
Participant 15	2	3	4	3	3	2	2	4	2	2	2	4	4
Participant 14	2	3	4	4	4	2	2	2	2	2	2	4	4
Participant 13	2	2	4	4	5	2	4	2	2	3	3	4	4
Participant 12	2	2	4	3	5	2	4	2	2	5	2	4	4
Participant 11	2	4	2	3	5	1	3	4	2	3	3	4	4
Participant 10	1	2	2	4	5	2	3	2	2	3	2	4	4
Participant 9	1	4	2	2	5	2	1	4	2	2	2	4	4
Participant 8	2	4	2	3	5	2	4	4	2	5	2	4	4
Participant 7	2	2	4	4	5	3	2	2	2	2	2	4	4
Participant 6	1	4	2	2	5	2	5	5	5	4	4	2	4
Participant 5	4	4	2	4	5	1	4	2	1	4	2	4	5
Participant 4	2	2	3	3	3	2	4	4	2	3	2	4	4
Participant 3	2	4	2	2	5	2	2	4	4	2	4	2	2
Participant 2	3	3	2	2	5	1	1	2	2	2	3	4	5
Participant 1	2	2	4	3	5	2	4	2	2	5	2	4	4

Road Event 4 – Motorway	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	1	5	1	1	5	1	5	5	5	4	5	1	5
Participant 19	1	5	2	2	4	2	3	4	2	2	3	3	4
Participant 18	2	5	2	2	5	1	5	4	4	5	5	2	5
Participant 17	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 16	2	5	1	1	5	2	3	5	5	3	4	3	3
Participant 15	1	5	1	2	5	1	4	5	4	5	5	1	5
Participant 14	1	5	1	1	5	2	5	5	5	5	5	1	5
Participant 13	1	5	1	1	5	2	4	5	5	5	5	1	5
Participant 12	1	5	1	1	5	2	3	5	4	4	4	1	3
Participant 11	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 10	1	5	1	1	5	2	4	5	2	2	4	3	4
Participant 9	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 8	1	5	1	2	5	2	4	5	5	5	5	1	5
Participant 7	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 6	2	4	2	2	4	2	3	4	2	2	4	3	4
Participant 5	2	5	1	2	5	1	5	5	4	5	5	2	5
Participant 4	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 3	2	5	2	1	5	2	3	5	4	3	4	3	3
Participant 2	1	5	2	2	5	2	4	4	5	5	1	3	5
Participant 1	1	5	1	1	4	2	5	4	5	5	4	1	4

Road Event 5 – Rumble strips	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	2	1	3	3	4	1	2	1	1	1	1	5	4
Participant 19	3	1	4	5	5	3	2	1	2	2	1	4	4
Participant 18	4	2	5	5	5	2	1	1	1	1	1	5	4
Participant 17	3	2	4	4	4	3	2	1	1	1	2	5	4
Participant 16	2	2	4	5	5	4	4	1	2	3	4	3	4
Participant 15	2	3	3	4	4	4	1	2	1	1	1	5	2
Participant 14	2	3	3	5	5	2	1	1	1	3	1	3	4
Participant 13	4	2	2	4	4	2	4	1	3	3	2	3	5
Participant 12	4	3	3	4	4	4	3	1	1	1	2	5	3
Participant 11	2	1	5	5	4	4	1	1	1	1	1	1	2
Participant 10	2	2	5	5	4	4	3	1	1	1	2	5	2
Participant 9	1	4	2	2	5	2	4	2	1	4	2	2	2
Participant 8	4	2	2	4	4	2	4	1	3	1	4	2	3
Participant 7	3	2	4	4	4	4	2	1	1	1	2	5	4
Participant 6	4	2	4	5	5	3	2	1	2	2	1	5	4
Participant 5	5	3	5	5	5	2	1	1	1	1	1	5	4
Participant 4	2	2	3	3	4	2	2	1	1	1	1	5	4
Participant 3	2	2	4	5	4	4	4	1	2	3	4	3	4
Participant 2	3	1	4	2	4	4	1	1	1	1	1	5	2
Participant 1	3	2	4	5	4	4	3	1	1	1	1	4	4

Road Event 6 – City Street	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	1	4	2	2	5	1	4	5	4	5	3	1	5
Participant 19	1	4	2	1	5	1	5	5	5	4	5	2	5
Participant 18	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 17	1	5	1	1	5	1	5	5	2	2	3	2	2
Participant 16	1	5	3	3	5	2	3	3	4	2	4	2	5
Participant 15	1	4	2	2	5	1	4	5	4	5	3	2	4
Participant 14	1	4	1	1	5	1	4	5	5	4	5	3	5
Participant 13	2	5	1	1	5	1	5	5	4	5	5	2	4
Participant 12	1	5	1	1	5	1	5	5	5	5	5	2	4
Participant 11	1	5	1	1	5	1	5	5	4	5	5	1	5
Participant 10	2	5	2	1	5	1	4	5	4	3	4	1	5
Participant 9	1	5	1	2	5	1	4	5	5	2	5	1	5
Participant 8	1	4	2	3	5	1	4	5	5	5	5	1	5
Participant 7	2	5	1	1	5	1	4	5	2	2	3	2	2
Participant 6	1	5	2	1	5	1	5	5	5	4	5	2	5
Participant 5	1	5	1	2	5	1	5	5	4	5	5	1	5
Participant 4	1	4	1	2	5	1	4	5	4	4	3	1	5
Participant 3	1	4	3	3	5	2	3	3	4	3	4	2	5
Participant 2	2	4	2	2	5	1	2	2	4	4	4	1	5
Participant 1	2	4	2	4	3	5	1	5	5	3	4	1	3

Road Event 7 – Cobblestone road	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	1	2	4	3	5	2	2	3	1	1	1	5	2
Participant 19	4	3	4	5	3	2	2	4	2	2	2	2	4
Participant 18	4	2	4	5	5	2	3	1	1	1	1	5	2
Participant 17	2	1	5	4	2	3	1	2	1	1	1	5	2
Participant 16	2	2	4	5	4	4	3	3	2	3	4	4	2
Participant 15	2	2	3	4	4	2	3	2	1	1	1	5	2
Participant 14	2	2	4	4	4	2	2	2	1	1	2	5	4
Participant 13	2	2	4	5	5	2	2	2	1	4	2	4	4
Participant 12	1	2	3	3	4	2	2	3	1	3	1	5	4
Participant 11	2	2	1	3	5	1	1	2	1	4	2	5	4
Participant 10	3	2	3	5	4	3	1	3	2	2	4	4	2
Participant 9	2	2	2	4	5	2	2	2	1	1	1	5	1
Participant 8	2	2	4	4	4	2	4	4	1	1	2	4	3
Participant 7	3	2	5	4	2	3	1	2	1	1	1	5	1
Participant 6	4	3	4	5	3	2	3	4	2	2	2	2	4
Participant 5	4	1	5	5	5	2	2	1	1	1	1	5	2
Participant 4	2	2	4	3	4	2	2	3	1	1	1	5	4
Participant 3	3	2	4	5	4	4	3	4	2	3	4	4	3
Participant 2	4	2	1	5	4	2	1	1	1	1	1	5	4
Participant 1	2	2	2	4	2	1	1	4	1	2	2	4	3

Road Event 8 – Large bump	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	1	1	2	2	5	1	4	5	2	4	3	2	5
Participant 19	3	4	3	3	5	2	4	5	2	2	3	4	5
Participant 18	2	3	4	5	4	1	5	2	2	5	2	2	5
Participant 17	2	3	5	3	4	2	2	2	1	2	3	2	2
Participant 16	2	1	3	5	5	1	2	4	2	1	2	4	3
Participant 15	1	4	2	3	5	2	4	5	2	4	3	2	5
Participant 14	1	4	3	3	4	2	3	3	2	4	3	3	4
Participant 13	2	4	3	3	5	1	5	5	2	4	4	1	4
Participant 12	1	4	2	5	5	1	4	5	2	4	3	2	5
Participant 11	1	4	3	2	5	1	5	4	3	4	4	1	4
Participant 10	2	4	5	5	4	1	5	2	1	1	1	4	4
Participant 9	4	4	1	5	5	1	3	5	1	1	1	5	3
Participant 8	2	4	4	2	5	2	2	4	2	4	3	2	4
Participant 7	2	4	5	3	4	2	2	2	2	2	3	2	2
Participant 6	2	4	3	3	5	1	4	5	2	2	3	4	5
Participant 5	4	4	4	5	4	1	5	2	2	5	2	2	5
Participant 4	1	2	2	3	5	1	4	4	2	3	3	2	5
Participant 3	3	1	4	5	5	1	2	2	1	1	2	4	3
Participant 2	2	1	4	5	4	2	1	1	1	1	1	5	4
Participant 1	2	4	3	3	4	1	2	2	1	2	3	4	5

Mercedes E Class

Road Event 1 – Small rubber bump	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	2	5	4	3	5	2	4	3	3	3	3	4	4
Participant 19	2	3	3	3	3	2	2	3	1	3	2	2	3
Participant 18	2	3	2	5	5	2	4	4	1	2	2	2	4
Participant 17	3	3	3	4	3	2	2	2	2	3	3	2	4
Participant 16	2	4	3	2	4	1	3	3	2	3	2	4	3
Participant 15	2	4	4	4	5	1	2	4	2	4	4	2	5
Participant 14	2	2	4	4	4	2	4	4	2	2	2	4	4
Participant 13	2	4	3	4	5	1	3	4	2	4	4	4	5
Participant 12	2	5	3	4	5	1	3	3	2	4	4	4	5
Participant 11	1	5	2	4	5	1	3	2	2	4	2	4	5
Participant 10	2	5	3	4	5	1	4	3	2	4	4	2	5
Participant 9	2	3	4	4	1	1	2	2	2	3	2	2	3
Participant 8	3	3	3	2	3	3	2	2	2	2	3	1	3
Participant 7	2	4	4	4	5	2	2	2	1	2	2	1	4
Participant 6	3	4	4	4	3	2	2	4	1	2	2	4	5
Participant 5	3	2	3	2	3	3	2	2	1	2	3	1	3
Participant 4	2	4	1	4	5	2	4	4	1	2	2	2	3
Participant 3	2	4	3	4	4	2	2	5	1	1	2	2	4
Participant 2	4	4	3	2	5	1	3	4	2	3	2	4	3
Participant 1	3	2	5	5	3	3	2	2	4	1	2	3	4

Road Event 2 – Broken road	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	4	1	3	5	3	3	2	3	2	1	2	4	3
Participant 19	4	2	5	4	5	2	3	2	2	2	1	4	3
Participant 18	5	2	2	4	4	2	3	3	1	1	1	5	3
Participant 17	4	1	4	3	4	4	3	2	2	2	2	3	4
Participant 16	2	2	5	5	5	3	3	2	2	2	2	4	3
Participant 15	4	2	2	4	4	4	4	4	2	2	1	5	4
Participant 14	2	2	2	4	4	2	4	2	2	2	1	2	4
Participant 13	4	1	2	4	4	4	4	3	2	2	1	5	4
Participant 12	4	1	4	4	4	2	2	4	2	2	2	3	4
Participant 11	4	1	4	5	4	2	2	2	1	1	1	5	4
Participant 10	4	2	4	4	4	2	2	4	2	2	2	2	4
Participant 9	5	1	5	5	5	1	2	1	1	1	1	5	2
Participant 8	5	2	4	3	4	1	3	4	1	2	2	4	4
Participant 7	5	2	2	5	4	2	2	2	1	1	1	5	4
Participant 6	5	1	5	4	3	3	2	1	1	1	1	5	5
Participant 5	4	2	4	3	4	2	2	2	1	2	2	4	4
Participant 4	5	2	4	5	4	4	3	2	2	3	2	5	3
Participant 3	4	2	3	3	5	4	2	3	1	2	1	5	2
Participant 2	4	2	5	5	5	1	2	2	2	2	2	4	3
Participant 1	5	2	5	5	2	4	2	1	1	1	2	5	1

Road Event 3 – Country road	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	3	4	3	3	4	3	4	3	2	3	2	4	3
Participant 19	2	2	4	4	5	1	4	2	3	2	2	4	4
Participant 18	3	2	2	4	3	2	3	4	2	2	3	4	5
Participant 17	2	4	3	1	5	2	3	5	2	3	3	2	3
Participant 16	1	2	4	3	5	1	3	3	2	3	4	4	4
Participant 15	2	5	1	1	5	1	4	5	4	4	4	2	4
Participant 14	2	2	2	2	5	1	4	4	2	4	2	2	4
Participant 13	2	3	1	1	5	1	4	5	4	4	4	2	4
Participant 12	1	2	2	2	4	3	4	2	2	2	2	4	4
Participant 11	2	2	4	2	4	1	2	2	2	2	2	4	5
Participant 10	2	3	2	2	4	2	4	2	2	2	2	4	4
Participant 9	2	4	4	4	5	1	3	3	2	3	2	4	3
Participant 8	5	3	4	3	3	3	3	4	2	2	2	4	2
Participant 7	4	4	2	4	4	2	4	4	2	2	2	4	5
Participant 6	4	2	4	4	3	4	4	2	2	2	2	4	4
Participant 5	5	2	4	4	3	3	3	4	2	2	2	4	2
Participant 4	2	4	2	1	5	2	3	5	2	3	4	2	2
Participant 3	1	4	2	2	5	2	4	5	2	2	2	4	4
Participant 2	2	2	4	4	5	1	3	3	2	3	4	4	4
Participant 1	2	2	3	4	3	3	3	2	2	2	2	4	2

Road Event 4 – Motorway	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	1	4	1	2	3	2	4	3	4	5	4	2	5
Participant 19	2	5	1	2	5	1	3	5	4	4	5	2	4
Participant 18	1	5	2	3	5	1	5	4	5	5	4	1	4
Participant 17	1	5	1	2	5	1	5	5	5	5	5	2	5
Participant 16	1	5	1	3	5	1	4	5	4	4	4	3	4
Participant 15	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 14	1	5	2	2	5	2	2	5	5	5	5	1	5
Participant 13	1	5	1	1	4	1	5	5	5	5	5	3	5
Participant 12	1	5	1	2	4	1	5	3	5	5	5	1	5
Participant 11	1	5	1	1	5	1	3	4	5	3	5	1	5
Participant 10	1	5	1	2	4	1	5	4	5	5	5	1	5
Participant 9	1	5	2	2	5	1	4	4	4	4	4	2	5
Participant 8	1	5	1	2	4	2	4	5	5	5	5	1	4
Participant 7	1	5	1	3	5	1	5	5	5	5	5	1	5
Participant 6	2	4	1	2	4	2	3	2	5	3	4	3	4
Participant 5	1	5	1	2	5	2	4	5	5	5	5	1	4
Participant 4	1	4	1	2	5	1	5	5	5	5	5	2	5
Participant 3	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 2	2	5	2	3	5	1	4	4	4	4	4	3	4
Participant 1	1	5	1	1	5	2	4	5	4	5	4	1	4

Road Event 5 – Rumble strips	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	2	1	3	3	5	3	2	1	2	1	2	4	4
Participant 19	3	2	3	3	3	3	1	1	2	2	1	5	3
Participant 18	4	2	3	4	5	2	1	4	1	2	1	4	3
Participant 17	2	2	3	4	4	1	4	2	1	1	1	5	2
Participant 16	2	2	3	3	3	3	2	1	1	2	1	5	2
Participant 15	4	1	3	5	4	2	1	1	1	1	1	5	2
Participant 14	2	2	4	4	4	3	2	2	1	2	2	2	2
Participant 13	4	1	3	5	4	2	1	2	1	1	1	5	2
Participant 12	2	2	2	4	4	2	1	1	2	1	1	5	4
Participant 11	2	2	4	4	4	2	1	1	2	1	1	5	5
Participant 10	4	2	2	4	4	2	1	1	2	1	1	5	4
Participant 9	5	1	5	5	5	1	1	5	1	1	1	5	2
Participant 8	2	2	1	2	5	2	3	1	4	2	3	1	3
Participant 7	2	1	2	2	5	1	1	5	1	1	1	5	3
Participant 6	4	2	4	4	5	2	1	1	4	1	1	5	5
Participant 5	2	4	1	2	5	2	3	1	4	2	3	1	4
Participant 4	2	2	3	4	4	2	4	2	1	2	2	5	2
Participant 3	3	1	2	4	4	2	2	1	1	1	1	4	2
Participant 2	3	2	3	3	3	3	2	1	1	2	1	5	2
Participant 1	4	2	3	3	4	4	1	1	1	2	1	4	2

Road Event 6 – City Street	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	2	5	2	2	4	2	5	4	3	3	3	1	4
Participant 19	1	4	2	2	4	1	3	4	3	4	4	2	5
Participant 18	2	4	1	2	5	1	4	4	4	5	4	3	5
Participant 17	1	4	1	3	5	2	4	5	3	5	5	3	4
Participant 16	2	4	2	3	5	2	4	3	2	3	4	2	5
Participant 15	2	4	2	2	5	1	4	5	5	5	5	5	5
Participant 14	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 13	2	4	2	2	5	1	3	5	5	5	5	5	5
Participant 12	2	4	2	2	4	2	3	4	3	4	4	2	5
Participant 11	1	4	1	2	5	1	3	3	3	4	5	2	4
Participant 10	2	4	2	2	5	2	3	4	3	4	4	2	5
Participant 9	2	5	2	3	5	1	4	4	2	3	2	2	3
Participant 8	2	4	1	1	5	1	5	4	4	4	5	2	4
Participant 7	2	4	1	2	4	1	4	4	5	4	4	4	5
Participant 6	1	5	1	2	5	1	3	5	2	4	4	1	5
Participant 5	2	4	1	1	5	1	5	5	4	4	5	2	4
Participant 4	1	4	1	2	5	4	4	5	2	4	5	1	5
Participant 3	1	4	1	2	5	1	5	5	4	5	4	1	5
Participant 2	1	4	2	3	5	2	4	3	2	3	4	2	5
Participant 1	2	4	2	2	4	2	5	5	4	4	4	1	4

Road Event 7 – Cobblestone road	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	3	2	3	5	5	2	2	3	2	2	1	4	4
Participant 19	3	1	4	4	4	2	3	4	1	2	2	4	3
Participant 18	4	2	3	2	4	1	2	2	2	1	1	3	2
Participant 17	4	2	4	5	4	2	2	2	1	1	1	5	3
Participant 16	2	1	5	5	5	2	2	4	1	1	1	5	1
Participant 15	4	2	2	4	4	2	2	4	2	1	2	4	4
Participant 14	2	2	4	2	5	2	2	5	2	1	2	2	2
Participant 13	4	2	2	4	4	2	2	3	2	2	2	3	4
Participant 12	4	2	4	4	5	2	2	2	1	2	2	4	3
Participant 11	2	2	4	4	5	1	2	2	2	2	2	4	5
Participant 10	4	2	4	4	4	2	2	2	1	2	2	4	5
Participant 9	5	1	4	5	4	1	1	1	1	1	1	5	2
Participant 8	3	2	3	4	4	3	3	2	1	2	1	5	1
Participant 7	4	1	2	2	4	1	2	2	1	1	1	2	4
Participant 6	2	2	2	4	4	1	1	2	1	1	2	4	5
Participant 5	4	2	3	4	4	3	3	2	1	2	1	5	1
Participant 4	4	1	4	5	5	1	2	2	1	1	1	5	2
Participant 3	2	3	2	4	4	2	4	2	1	2	1	3	2
Participant 2	5	1	5	5	5	2	2	5	1	1	1	5	1
Participant 1	4	2	4	4	3	4	1	2	2	2	1	3	2

Road Event 8 – Large bump	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	2	3	3	2	5	2	2	3	3	3	2	4	4
Participant 19	1	3	3	3	4	1	2	2	2	4	3	2	4
Participant 18	2	3	4	3	4	1	2	4	2	2	4	2	4
Participant 17	3	4	1	5	5	2	3	4	2	2	3	3	5
Participant 16	1	3	2	4	5	1	2	2	2	4	4	2	4
Participant 15	2	4	2	2	5	1	2	5	2	4	4	2	4
Participant 14	2	4	2	4	4	2	2	4	4	2	2	4	2
Participant 13	2	4	2	2	5	2	2	4	2	4	4	2	4
Participant 12	1	4	2	2	5	1	4	4	4	4	3	2	5
Participant 11	2	4	4	3	4	1	2	2	2	2	2	2	5
Participant 10	2	4	2	2	5	1	4	4	4	4	3	2	5
Participant 9	2	4	4	4	5	1	2	3	2	2	2	2	3
Participant 8	2	3	3	3	4	2	2	2	2	2	3	3	3
Participant 7	2	2	4	4	4	2	1	4	1	2	1	4	4
Participant 6	1	2	4	2	4	2	2	2	4	2	2	4	5
Participant 5	2	4	2	3	4	2	2	2	2	2	3	2	4
Participant 4	4	4	1	5	5	1	1	5	1	1	1	5	4
Participant 3	2	4	2	4	4	1	4	5	2	3	4	4	4
Participant 2	1	2	2	4	5	1	2	2	2	4	4	2	5
Participant 1	2	3	3	4	4	2	3	3	3	3	4	2	4

Volkswagen Polo

Road Type	Road Event 1 Small rubber bump													Road Event 2 Broken road												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	3	3	3	5	4	2	3	4	2	3	2	3	4	4	2	4	4	4	2	3	3	2	2	2	4	4
Participant 19	4	2	4	4	3	2	3	2	1	2	2	2	4	5	1	5	5	2	4	2	2	1	1	1	5	4
Participant 18	3	2	5	5	4	1	2	1	2	1	3	3	3	5	1	5	5	3	4	1	1	1	1	1	5	2
Participant 17	2	1	5	5	3	2	1	2	1	1	2	3	3	2	1	1	5	2	2	2	1	1	1	3	5	2
Participant 16	3	2	4	4	3	2	2	2	2	2	2	2	4	5	1	5	5	2	4	2	2	1	1	1	5	4
Participant 15	5	2	5	5	4	3	3	2	1	1	2	3	4	5	1	5	5	3	4	1	1	1	1	1	4	2
Participant 14	2	2	4	4	3	2	1	2	1	1	2	2	3	4	2	4	4	4	1	3	2	2	2	2	4	4
Participant 13	2	1	5	5	3	2	2	1	1	1	1	3	2	2	1	1	5	2	2	2	1	1	1	3	5	3
Participant 12	5	1	4	5	4	2	2	2	1	1	3	4	4	5	1	4	5	3	4	2	2	1	1	1	5	3
Participant 11	4	4	2	4	4	1	4	4	2	3	2	2	5	5	1	4	4	3	3	1	1	1	1	1	4	2
Participant 10	2	2	4	4	4	2	2	2	2	2	2	2	4	5	1	5	5	2	4	2	2	1	1	1	5	4
Participant 9	5	2	5	5	4	2	3	2	1	1	2	3	4	5	1	5	5	4	4	2	2	1	1	1	5	2
Participant 8	5	1	4	5	4	2	2	2	1	1	3	4	4	5	1	5	5	3	4	1	1	1	1	1	5	2
Participant 7	4	1	5	4	2	2	2	1	1	1	2	5	5	5	1	5	5	4	2	2	2	1	1	1	5	2
Participant 6	4	4	2	4	4	1	4	4	2	4	2	2	5	4	2	4	4	4	2	3	3	2	2	2	4	4
Participant 5	1	2	4	4	5	1	2	2	1	2	2	4	3	2	1	4	2	4	2	1	1	2	1	1	4	4
Participant 4	2	2	4	4	3	2	1	2	1	1	2	2	3	2	1	1	5	2	2	2	1	1	1	3	5	2
Participant 3	4	2	4	4	4	2	2	2	2	3	2	4	3	5	1	5	5	5	2	1	5	1	1	1	5	2
Participant 2	2	3	4	4	4	3	2	4	1	2	3	2	4	4	1	5	5	4	3	1	1	1	1	1	5	2
Participant 1	2	1	5	5	3	2	1	1	1	1	1	3	2	5	1	5	5	3	4	1	1	1	1	1	5	2

Road Type	Road Event 3 Country road													Road Event 4 Motorway												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	2	4	2	2	4	2	3	3	3	2	4	2	4	1	5	1	2	5	1	5	5	5	4	5	1	4
Participant 19	2	4	4	2	5	2	4	4	2	4	4	4	4	1	5	1	2	5	1	5	5	5	5	5	1	5
Participant 18	5	1	5	5	3	3	2	2	2	1	2	4	3	1	4	3	2	5	2	3	3	5	2	2	1	5
Participant 17	2	4	2	4	2	2	2	2	2	2	2	5	2	1	5	1	1	5	1	5	5	2	5	5	1	3
Participant 16	2	4	4	2	5	1	4	3	2	4	4	4	4	2	4	1	2	5	1	5	5	4	5	5	1	5
Participant 15	3	3	4	4	4	4	3	4	2	3	2	4	4	1	4	2	1	5	1	5	5	4	4	5	1	5
Participant 14	2	4	2	4	2	1	2	3	2	3	2	5	2	1	5	1	2	5	1	5	4	3	5	5	2	5
Participant 13	5	2	5	5	3	3	2	2	3	2	2	4	3	1	4	2	1	5	2	3	3	5	2	2	1	4
Participant 12	4	3	3	4	4	2	4	4	2	3	2	4	4	1	5	1	2	5	2	5	5	4	5	5	1	4
Participant 11	2	4	2	3	4	2	3	3	3	2	4	2	5	1	4	1	2	5	1	5	5	5	4	5	1	5
Participant 10	2	4	4	2	5	2	4	4	2	4	4	4	4	1	5	1	2	5	1	5	5	5	5	5	1	5
Participant 9	4	3	4	4	4	4	3	4	2	3	2	4	4	1	4	2	1	5	1	5	5	4	4	5	1	5
Participant 8	4	3	4	4	4	2	4	4	3	3	2	4	5	1	5	1	2	5	1	5	5	4	5	5	1	5
Participant 7	2	2	4	4	4	1	4	4	2	2	2	2	4	1	5	2	1	5	1	4	4	4	4	5	1	5
Participant 6	2	4	2	2	4	2	3	3	3	2	4	2	4	1	5	1	2	5	1	5	5	5	4	5	1	4
Participant 5	2	2	4	4	2	4	2	2	2	2	2	2	4	1	5	1	1	5	1	3	4	5	4	5	1	5
Participant 4	2	4	2	4	2	2	2	2	2	2	2	5	2	1	5	1	1	5	1	5	5	2	5	5	1	3
Participant 3	4	2	4	4	2	2	2	2	2	2	2	4	2	1	4	3	2	5	1	2	3	3	4	4	2	5
Participant 2	2	3	4	4	4	3	2	2	2	2	2	4	4	1	5	1	2	5	1	5	5	4	4	5	1	4
Participant 1	5	1	5	5	3	3	2	2	2	1	2	4	3	1	4	3	2	5	2	3	3	5	2	2	1	5

Road Type	Road Event 5 Rumble strips													Road Event 6 City Street												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	5	1	4	5	5	2	2	1	1	1	2	5	4	2	5	1	2	5	2	5	5	4	4	4	2	5
Participant 19	4	4	4	4	5	2	2	1	2	1	1	5	4	1	5	1	2	5	1	5	5	4	5	4	1	5
Participant 18	3	1	2	2	4	2	1	1	3	1	1	4	4	2	4	3	4	4	2	2	3	3	3	4	2	2
Participant 17	2	2	2	4	2	2	1	1	2	1	1	2	2	1	4	2	3	5	2	5	5	2	5	4	2	5
Participant 16	5	2	5	5	3	4	1	1	1	1	2	5	2	1	5	1	2	5	1	5	4	4	5	3	1	5
Participant 15	4	1	5	5	3	3	1	1	1	1	2	5	2	3	4	2	2	5	2	4	5	2	4	4	4	4
Participant 14	4	1	2	2	5	2	1	1	3	1	1	4	3	1	4	3	3	5	2	5	5	2	5	4	2	5
Participant 13	4	3	4	4	4	2	2	1	2	1	1	5	4	2	4	3	4	4	2	3	3	3	3	4	2	2
Participant 12	5	2	4	5	5	2	2	1	1	1	2	5	3	2	4	2	3	4	2	4	5	2	3	3	2	4
Participant 11	2	2	2	4	2	2	1	1	2	1	1	2	3	2	5	2	3	5	2	4	5	4	4	4	2	5
Participant 10	4	4	4	4	5	2	2	1	2	1	1	5	4	1	5	1	2	5	1	5	5	4	5	4	1	5
Participant 9	5	1	5	5	3	4	1	1	1	1	1	5	2	3	4	2	3	5	2	4	5	2	4	4	4	4
Participant 8	4	2	5	5	3	4	1	1	1	1	1	5	2	2	4	2	3	4	2	4	4	2	3	3	2	4
Participant 7	2	2	4	4	4	2	2	1	4	2	2	4	4	1	5	1	1	5	1	4	5	5	4	5	1	5
Participant 6	5	1	4	5	5	2	2	1	1	1	2	5	4	2	5	1	2	5	2	5	5	4	4	4	2	5
Participant 5	2	2	4	4	4	2	1	1	2	1	2	4	5	2	5	1	2	5	1	5	4	4	4	4	2	4
Participant 4	2	2	2	4	2	2	1	1	2	1	1	2	2	1	4	2	3	5	2	5	5	2	5	4	2	5
Participant 3	4	1	5	5	2	2	1	1	1	1	1	5	1	1	4	2	2	4	1	4	3	4	4	4	2	5
Participant 2	4	1	5	5	3	4	1	1	1	1	1	5	2	1	4	2	2	4	1	4	3	4	3	4	1	5
Participant 1	3	1	2	2	4	2	1	1	3	1	1	4	4	2	4	3	4	4	2	2	3	3	3	4	2	2

Road Type	Road Event 7 Cobblestone road													Road Event 8 Large bump												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	5	2	4	4	4	1	2	2	2	2	2	5	5	2	4	3	4	4	1	4	3	3	5	4	2	5
Participant 19	4	2	4	4	5	4	2	4	1	1	1	5	4	2	5	2	3	4	2	4	5	4	4	4	2	4
Participant 18	5	1	4	4	3	4	1	5	5	1	1	5	3	3	3	4	5	5	2	2	2	1	2	2	4	5
Participant 17	2	1	5	5	2	2	2	2	1	2	1	4	4	1	4	2	3	2	2	2	5	2	2	4	4	4
Participant 16	4	1	4	4	5	4	2	4	1	2	1	5	4	2	4	2	3	4	2	5	5	4	3	4	3	4
Participant 15	4	2	4	5	3	2	2	4	2	1	1	5	3	3	5	3	4	5	2	4	5	2	4	3	2	4
Participant 14	3	2	5	5	3	2	2	3	1	1	1	4	4	2	4	2	3	2	2	2	5	2	2	3	4	4
Participant 13	5	1	4	4	3	3	1	5	5	1	1	5	3	2	4	4	5	5	2	2	2	1	2	3	4	5
Participant 12	4	2	4	5	4	3	2	2	1	1	1	4	2	3	3	3	3	5	2	4	5	3	2	3	2	5
Participant 11	5	1	4	4	4	1	2	2	2	2	2	5	5	2	4	3	4	4	1	3	3	3	5	4	2	4
Participant 10	4	2	4	4	5	4	2	4	1	1	1	5	4	2	5	2	3	4	2	4	5	4	4	4	2	4
Participant 9	4	2	4	5	4	2	2	4	1	1	1	5	3	3	4	2	4	5	2	4	5	2	4	3	3	4
Participant 8	5	1	4	5	4	3	2	2	1	1	1	5	2	3	4	3	3	4	2	4	5	3	2	3	2	5
Participant 7	4	2	4	4	4	2	2	2	1	2	2	4	5	1	4	2	2	4	1	4	2	2	4	5	2	5
Participant 6	5	2	4	4	4	1	2	2	2	2	2	5	5	2	4	3	4	4	1	4	3	3	5	4	2	5
Participant 5	2	2	2	4	4	2	2	2	2	2	2	4	4	1	4	2	4	5	1	2	2	2	2	4	4	5
Participant 4	2	1	5	5	2	2	2	2	1	2	1	4	4	1	4	2	3	2	2	2	5	2	2	4	4	4
Participant 3	5	1	5	5	2	4	1	1	1	1	1	5	1	2	2	2	4	2	1	2	2	2	2	2	4	4
Participant 2	4	1	4	5	3	4	1	1	1	1	1	5	2	2	3	4	4	4	2	4	3	2	3	2	3	4
Participant 1	5	1	4	4	3	4	1	5	5	1	1	5	3	3	3	4	5	5	2	2	2	1	2	2	4	5

Volkswagen Passat

Road Type	Road Event 1 Small rubber bump													Road Event 2 Broken road												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	2	2	4	4	5	1	4	4	2	2	2	2	4	2	2	4	5	5	2	2	4	1	2	2	5	2
Participant 19	3	4	3	3	5	2	2	5	2	2	4	2	4	5	2	4	5	4	4	2	3	1	1	1	5	3
Participant 18	5	3	5	5	3	3	1	4	1	2	1	1	3	5	1	5	5	1	5	1	2	1	1	2	5	3
Participant 17	2	4	2	4	5	1	4	4	2	4	2	2	5	4	1	4	5	4	4	2	2	1	2	2	4	4
Participant 16	2	4	4	4	5	2	2	2	1	2	2	1	4	5	2	2	5	4	2	2	2	1	1	1	5	4
Participant 15	3	4	4	4	3	2	2	4	1	2	2	4	5	5	1	5	4	3	3	2	1	1	1	2	5	5
Participant 14	3	3	3	2	3	3	2	2	1	2	3	1	3	4	2	4	3	4	2	2	2	1	2	2	4	4
Participant 13	2	2	5	5	3	1	1	4	1	1	1	4	5	4	3	4	5	5	3	1	2	1	1	1	4	5
Participant 12	5	2	5	4	3	3	1	3	1	1	2	2	3	5	1	4	5	5	4	2	2	1	2	1	4	3
Participant 11	2	2	4	5	4	3	2	3	1	1	2	1	4	4	3	3	4	4	3	2	2	2	1	2	4	4
Participant 10	2	3	4	5	5	1	3	3	1	1	2	2	4	4	4	4	5	4	1	4	2	1	2	1	5	3
Participant 9	2	2	4	4	5	1	4	4	2	2	2	2	4	2	2	4	5	5	2	2	4	1	2	2	5	2
Participant 8	2	4	4	4	5	2	2	2	1	2	2	1	4	5	2	2	5	4	2	2	2	1	1	1	5	4
Participant 7	3	4	4	4	3	2	2	4	1	2	2	4	5	5	1	5	4	3	3	2	1	1	1	2	5	5
Participant 6	2	4	2	4	5	1	4	4	2	4	2	2	5	4	1	4	5	4	4	2	2	1	2	1	4	4
Participant 5	2	2	4	5	5	1	2	2	1	2	2	4	5	5	4	4	5	5	1	4	2	1	1	1	5	5
Participant 4	4	2	4	5	5	2	4	3	1	1	2	2	4	5	1	5	5	2	4	1	2	1	1	1	5	1
Participant 3	2	2	5	4	4	2	2	4	1	2	2	2	2	5	1	4	4	4	4	2	1	1	2	1	5	3
Participant 2	2	1	5	5	5	1	1	1	1	1	1	2	4	5	1	4	5	4	1	1	1	1	1	1	5	4
Participant 1	5	4	2	4	5	2	4	4	2	2	1	2	3	4	3	3	4	4	4	1	2	1	2	1	4	4

Road Type	Road Event 3 Country road													Road Event 4 Motorway												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	1	4	2	2	5	2	1	4	2	2	2	4	4	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 19	2	4	2	3	5	2	4	4	2	5	2	4	4	1	5	1	2	4	2	4	5	5	5	5	1	5
Participant 18	2	2	4	4	5	3	2	2	2	2	2	4	4	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 17	1	4	2	2	5	2	5	5	5	4	4	2	4	2	4	2	2	4	2	3	4	2	2	5	3	4
Participant 16	4	4	2	4	4	2	4	4	2	2	3	4	5	1	5	1	3	5	1	5	5	5	5	5	1	5
Participant 15	4	2	4	4	3	4	4	2	2	3	3	4	4	2	4	1	2	4	2	3	2	5	3	5	3	4
Participant 14	5	2	4	4	3	3	3	4	2	2	2	4	2	1	5	1	2	5	2	4	5	5	5	5	1	4
Participant 13	2	2	4	4	5	2	4	2	2	3	3	4	4	1	5	1	1	5	2	4	5	5	5	5	1	5
Participant 12	2	2	4	3	5	2	4	2	2	5	2	4	4	1	5	1	1	5	2	3	5	4	4	4	1	3
Participant 11	2	4	2	3	5	1	3	4	2	3	3	4	4	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 10	1	2	2	4	5	2	3	2	2	3	2	4	4	1	5	1	1	5	2	4	5	2	2	4	3	4
Participant 9	1	4	2	2	5	2	1	4	2	2	2	4	4	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 8	4	4	2	4	4	2	4	4	2	2	3	4	5	1	5	1	3	5	1	5	5	5	5	5	1	5
Participant 7	4	2	4	4	3	4	4	2	2	3	3	4	4	2	4	1	2	4	2	3	2	5	3	5	3	4
Participant 6	1	4	2	2	5	2	5	5	5	4	4	2	4	2	4	2	2	4	2	3	4	2	2	4	3	4
Participant 5	4	4	2	4	5	1	4	2	1	4	2	4	5	2	5	1	2	5	1	5	5	4	5	5	2	5
Participant 4	2	2	3	3	3	2	4	4	2	3	2	4	4	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 3	2	4	2	2	5	2	2	4	4	2	4	2	2	2	5	2	1	5	2	3	5	4	3	4	3	3
Participant 2	3	3	2	2	5	1	1	2	2	2	3	4	5	1	5	2	2	5	2	4	4	5	5	1	3	5
Participant 1	2	2	4	3	5	2	4	2	2	5	2	4	4	1	5	1	1	4	2	5	4	5	5	4	1	4

Road Type	Road Event 5 Rumble strips													Road Event 6 City Street												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	1	4	2	2	5	2	4	2	1	4	2	2	2	1	5	1	2	5	1	4	5	5	2	5	1	5
Participant 19	4	2	2	4	4	2	4	1	3	1	4	2	3	1	4	2	3	4	1	4	5	5	5	5	1	5
Participant 18	3	2	4	4	4	4	2	1	1	1	3	5	4	2	5	1	1	5	1	4	5	2	2	4	2	2
Participant 17	4	2	4	5	5	3	2	1	2	2	1	5	4	1	5	2	1	5	1	5	5	5	4	5	2	5
Participant 16	2	1	2	2	5	1	1	5	1	1	2	5	3	2	4	1	2	4	1	4	4	5	4	4	4	5
Participant 15	4	2	4	4	4	2	1	1	4	1	2	5	5	1	5	1	2	5	1	3	5	2	4	4	1	5
Participant 14	2	4	1	2	5	2	3	1	4	2	3	1	4	2	4	1	1	5	1	5	5	4	4	5	2	4
Participant 13	4	2	2	4	4	2	4	1	3	3	2	3	5	2	5	1	1	5	1	5	5	4	5	5	2	4
Participant 12	4	3	3	4	4	4	3	1	1	1	2	5	3	1	5	1	1	5	1	5	5	5	5	5	2	4
Participant 11	2	1	5	5	4	4	1	1	1	1	1	1	2	1	5	1	1	5	1	5	5	4	5	5	1	5
Participant 10	2	2	5	5	4	4	3	1	1	1	2	5	2	2	5	2	1	5	1	4	5	4	3	4	1	5
Participant 9	1	4	2	2	5	2	4	2	1	4	2	2	2	1	5	1	2	5	1	4	5	5	2	5	1	5
Participant 8	2	1	2	2	5	1	1	5	1	1	2	5	3	2	4	1	2	4	1	4	4	5	4	4	4	5
Participant 7	4	2	4	4	4	2	1	1	4	1	2	5	5	1	5	1	2	5	1	3	5	2	4	4	1	5
Participant 6	4	2	4	5	5	3	2	1	2	2	1	5	4	1	5	2	1	5	1	5	5	5	4	5	2	5
Participant 5	5	3	5	5	5	2	1	1	1	1	1	5	4	1	5	1	2	5	1	5	5	4	5	5	1	5
Participant 4	2	2	3	3	4	2	2	1	1	1	1	5	4	1	4	1	2	5	1	4	5	4	4	3	1	5
Participant 3	2	2	4	5	4	4	4	1	2	3	4	3	4	1	4	3	3	5	2	3	3	4	3	4	2	5
Participant 2	3	1	4	2	4	4	1	1	1	1	1	5	2	2	4	2	2	5	1	2	2	4	4	4	1	5
Participant 1	3	2	4	5	4	4	3	1	1	1	1	4	4	2	4	2	4	3	5	1	5	5	3	4	1	3

Road Type	Road Event 7 Cobblestone road													Road Event 8 Large bump												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	2	2	2	4	4	2	2	2	1	2	1	5	1	4	4	1	5	5	1	3	5	1	1	2	5	3
Participant 19	2	2	4	4	4	2	4	4	1	1	2	4	3	2	4	4	2	4	2	2	4	2	4	3	2	4
Participant 18	3	3	5	4	2	3	1	2	1	1	1	5	1	2	4	5	3	4	2	2	2	2	2	3	2	2
Participant 17	4	3	4	5	3	2	3	4	2	2	2	2	4	2	4	3	3	4	1	4	5	2	2	3	4	5
Participant 16	4	2	2	2	3	1	2	2	1	1	1	2	4	2	3	4	4	3	2	1	4	1	2	2	4	4
Participant 15	2	2	2	4	4	1	1	2	1	1	2	4	5	1	3	4	2	4	2	2	2	4	2	2	4	5
Participant 14	4	2	3	4	4	3	3	2	1	2	2	5	1	2	4	2	3	4	2	2	2	2	2	3	2	4
Participant 13	2	2	4	5	5	2	2	2	1	4	2	4	4	2	4	3	3	5	1	5	5	2	4	4	1	4
Participant 12	1	2	3	3	4	2	2	3	1	3	1	5	4	1	4	2	5	5	1	4	5	2	4	3	2	5
Participant 11	2	2	1	3	5	1	1	2	1	4	2	5	4	1	4	3	2	5	1	5	4	3	4	4	1	4
Participant 10	3	2	3	5	4	3	1	3	2	2	4	4	2	2	4	5	5	4	1	5	2	1	1	1	4	4
Participant 9	2	2	2	4	5	2	2	2	1	1	1	5	1	4	4	1	5	5	1	3	5	1	1	1	5	3
Participant 8	4	2	2	2	3	1	2	2	1	1	1	2	4	2	3	4	4	3	2	1	4	1	2	2	4	4
Participant 7	2	2	2	4	4	1	1	2	1	1	2	4	5	1	3	4	2	4	2	2	2	4	2	2	4	5
Participant 6	4	3	4	5	3	2	3	4	2	2	2	2	4	2	4	3	3	5	1	4	5	2	2	3	4	5
Participant 5	4	1	5	5	5	2	2	1	1	1	1	5	2	4	4	4	5	4	1	5	2	2	5	2	2	5
Participant 4	2	2	4	3	4	2	2	3	1	1	1	5	4	1	2	2	3	5	1	4	4	2	3	3	2	5
Participant 3	3	2	4	5	4	4	3	4	2	3	4	4	3	3	1	4	5	5	1	2	2	1	1	2	4	3
Participant 2	4	2	1	5	4	2	1	1	1	1	1	5	4	2	1	4	5	4	2	1	1	1	1	1	5	4
Participant 1	2	2	2	4	2	1	1	4	1	2	2	4	3	2	4	3	3	4	1	2	2	1	2	3	4	5

Renault Clio

Road Type	Road Event 1 Small rubber bump													Road Event 2 Broken road												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	4	1	5	4	2	2	2	1	1	1	2	5	5	5	1	5	5	4	2	2	2	1	1	1	5	2
Participant 19	4	4	2	4	4	1	4	4	2	4	2	2	5	4	2	4	4	4	2	3	3	1	2	2	4	3
Participant 18	1	2	4	4	5	1	2	2	1	2	2	4	3	2	1	4	3	4	2	1	1	1	1	1	4	4
Participant 17	2	2	4	4	3	2	1	2	1	1	2	2	3	2	1	1	5	2	2	2	1	1	1	3	5	2
Participant 16	2	1	5	5	3	2	1	1	1	1	1	3	2	5	1	5	5	3	4	1	1	1	1	1	5	2
Participant 15	2	4	4	4	5	1	2	4	2	4	4	2	5	4	2	2	4	4	4	4	4	2	2	1	5	4
Participant 14	2	2	4	4	4	2	4	4	2	2	2	4	4	2	2	2	4	4	2	4	2	2	2	1	2	4
Participant 13	2	4	3	4	5	1	3	4	2	4	4	4	5	4	1	2	4	4	4	4	3	2	2	1	5	4
Participant 12	2	5	3	4	5	1	3	3	2	4	4	4	5	4	1	4	4	4	2	2	4	2	2	2	3	4
Participant 11	1	5	2	4	5	1	3	2	2	4	2	4	5	4	1	4	5	4	2	2	2	1	1	1	5	4
Participant 10	2	5	3	4	5	1	4	3	2	4	4	2	5	4	2	4	4	4	2	2	4	2	2	2	2	4
Participant 9	4	1	5	4	2	2	2	1	1	1	2	5	5	5	1	5	5	4	2	2	2	1	1	1	5	2
Participant 8	4	4	2	4	4	1	4	4	2	4	2	2	5	4	2	4	4	4	2	3	3	1	2	2	4	3
Participant 7	1	2	4	4	5	1	2	2	1	2	2	4	3	2	1	4	3	4	2	1	1	1	1	1	4	4
Participant 6	2	2	4	4	3	2	1	2	1	1	2	2	3	2	1	1	5	2	2	2	1	1	1	3	5	2
Participant 5	2	1	5	5	3	2	1	1	1	1	1	3	2	5	1	5	5	3	4	1	1	1	1	1	5	2
Participant 4	2	4	1	4	5	2	4	4	1	2	2	2	3	5	2	4	5	4	4	3	2	2	3	2	5	3
Participant 3	2	4	3	4	4	2	2	5	1	1	2	2	4	4	2	3	3	5	4	2	3	1	2	1	5	2
Participant 2	4	4	3	2	5	1	3	4	2	3	2	4	3	4	2	5	5	5	1	2	2	2	2	2	4	3
Participant 1	3	2	5	5	3	3	2	2	4	1	2	3	4	5	2	5	5	2	4	2	1	1	1	2	5	1

Road Type	Road Event 3 Country road													Road Event 4 Motorway												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	2	2	4	4	4	1	4	4	2	2	2	2	2	1	5	2	1	5	1	4	4	4	4	4	1	4
Participant 19	2	4	2	2	4	2	3	3	2	2	4	2	4	1	5	1	2	5	1	5	5	5	4	4	1	4
Participant 18	2	2	4	4	2	4	2	2	2	2	2	2	4	1	5	1	1	5	1	3	4	5	4	5	1	5
Participant 17	2	4	2	4	2	2	2	2	1	2	2	5	2	1	5	1	1	5	1	5	5	2	5	5	1	3
Participant 16	5	1	5	5	3	3	2	2	2	1	2	4	3	1	4	3	2	5	2	3	3	5	2	2	1	5
Participant 15	2	5	1	1	5	1	4	5	4	4	4	2	4	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 14	2	2	2	2	5	1	4	4	2	4	2	2	4	1	5	2	2	5	2	2	5	5	5	5	1	5
Participant 13	2	3	1	1	5	1	4	5	4	4	4	2	4	1	5	1	1	4	1	5	5	5	5	5	3	5
Participant 12	1	2	2	2	4	3	4	2	2	2	2	4	4	1	5	1	2	4	1	5	3	5	5	5	1	5
Participant 11	2	2	4	2	4	1	2	2	2	2	2	4	5	1	5	1	1	5	1	3	4	5	3	5	1	5
Participant 10	2	3	2	2	4	2	4	2	2	2	2	4	4	1	5	1	2	4	1	5	4	5	5	5	1	5
Participant 9	2	2	4	4	4	1	4	4	2	2	2	2	2	1	5	2	1	5	1	4	4	4	4	4	1	4
Participant 8	2	4	2	2	4	2	3	3	2	2	4	2	4	1	5	1	2	5	1	5	5	5	4	4	1	4
Participant 7	2	2	4	4	2	4	2	2	2	2	2	2	4	1	5	1	1	5	1	3	4	5	4	5	1	5
Participant 6	2	4	2	4	2	2	2	2	1	2	2	5	2	1	5	1	1	5	1	5	5	2	5	5	1	3
Participant 5	5	1	5	5	3	3	2	2	2	1	2	4	3	1	4	3	2	5	2	3	3	5	2	2	1	5
Participant 4	2	4	2	1	5	2	3	5	2	3	4	2	2	1	4	1	2	5	1	5	5	5	5	5	2	5
Participant 3	1	4	2	2	5	2	4	5	2	2	2	4	4	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 2	2	2	4	4	5	1	3	3	2	3	4	4	4	2	5	2	3	5	1	4	4	4	4	4	3	4
Participant 1	2	2	3	4	3	3	3	2	2	2	2	4	2	1	5	1	1	5	2	4	5	4	5	4	1	4

Road Type	Road Event 5 Rumble strips													Road Event 6 City Street												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	2	2	4	4	4	2	2	1	4	2	2	4	3	1	5	1	1	5	1	4	5	3	4	4	1	5
Participant 19	5	1	4	5	5	2	2	1	1	1	1	5	2	2	5	1	2	5	2	5	5	4	4	3	2	5
Participant 18	2	2	4	4	4	2	1	1	2	1	2	4	5	2	5	1	2	5	1	5	4	3	4	4	2	4
Participant 17	2	2	2	4	2	2	1	1	2	1	1	2	2	1	4	2	3	5	2	5	5	2	5	3	2	5
Participant 16	3	1	2	2	4	2	1	1	3	1	1	4	4	2	4	3	4	4	2	2	3	3	3	4	2	2
Participant 15	4	1	3	5	4	2	1	1	1	1	1	5	2	2	4	2	2	5	1	4	5	5	5	5	5	5
Participant 14	2	2	4	4	4	3	2	2	1	2	2	2	2	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 13	4	1	3	5	4	2	1	2	1	1	1	5	2	2	4	2	2	5	1	3	5	5	5	5	5	5
Participant 12	2	2	2	4	4	2	1	1	2	1	1	5	4	2	4	2	2	4	2	3	4	3	4	4	2	5
Participant 11	2	2	4	4	4	2	1	1	2	1	1	5	5	1	4	1	2	5	1	3	3	3	4	5	2	4
Participant 10	4	2	2	4	4	2	1	1	2	1	1	5	4	2	4	2	2	5	2	3	4	3	4	4	2	5
Participant 9	2	2	4	4	4	2	2	1	4	2	2	4	3	1	5	1	1	5	1	4	5	3	4	4	1	5
Participant 8	5	1	4	5	5	2	2	1	1	1	1	5	2	2	5	1	2	5	2	5	5	4	4	3	2	5
Participant 7	2	2	4	4	4	2	1	1	2	1	2	4	5	2	5	1	2	5	1	5	4	3	4	4	2	4
Participant 6	2	2	2	4	2	2	1	1	2	1	1	2	2	1	4	2	3	5	2	5	5	2	5	3	2	5
Participant 5	3	1	2	2	4	2	1	1	3	1	1	4	4	2	4	3	4	4	2	2	3	3	3	4	2	2
Participant 4	2	2	3	4	4	2	4	2	1	2	2	5	2	1	4	1	2	5	4	4	5	2	4	5	1	5
Participant 3	3	1	2	4	4	2	2	1	1	1	1	4	2	1	4	1	2	5	1	5	5	4	5	4	1	5
Participant 2	3	2	3	3	3	3	2	1	1	2	1	5	2	1	4	2	3	5	2	4	3	2	3	4	2	5
Participant 1	4	2	3	3	4	4	1	1	1	2	1	4	2	2	4	2	2	4	2	5	5	4	4	4	1	4

Road Type	Road Event 7 Cobblestone road													Road Event 8 Large bump												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	4	2	4	5	4	2	2	2	1	2	1	4	5	1	4	2	3	4	1	4	2	2	4	3	2	5
Participant 19	5	2	4	4	4	1	2	2	2	2	1	5	5	2	4	3	4	4	1	4	3	1	5	2	2	5
Participant 18	2	2	2	4	4	2	2	2	2	2	2	4	4	1	4	2	4	5	1	2	2	2	2	4	4	4
Participant 17	2	1	5	5	2	2	2	2	1	2	1	4	4	1	4	2	3	2	2	2	5	2	2	2	4	4
Participant 16	5	1	4	5	3	4	1	5	1	1	1	5	3	3	3	4	5	5	2	2	2	1	2	2	4	5
Participant 15	4	2	2	4	4	2	2	4	2	1	2	4	4	2	4	2	2	5	1	2	5	2	4	4	2	4
Participant 14	2	2	4	2	5	2	2	5	2	1	2	2	2	2	4	2	4	4	2	2	4	4	2	2	4	2
Participant 13	4	2	2	4	4	2	2	3	2	2	2	3	4	2	4	2	2	5	2	2	4	2	4	4	2	4
Participant 12	4	2	4	4	5	2	2	2	1	2	2	4	3	1	4	2	2	5	1	4	4	4	4	3	2	5
Participant 11	2	2	4	4	5	1	2	2	2	2	2	4	5	2	4	4	3	4	1	2	2	2	2	2	2	5
Participant 10	4	2	4	4	4	2	2	2	1	2	2	4	5	2	4	2	2	5	1	4	4	4	4	3	2	5
Participant 9	4	2	4	5	4	2	2	2	1	2	1	4	5	1	4	2	3	4	1	4	2	2	4	3	2	5
Participant 8	5	2	4	4	4	1	2	2	2	2	1	5	5	2	4	3	4	4	1	4	3	1	5	2	2	5
Participant 7	2	2	2	4	4	2	2	2	2	2	2	4	4	1	4	2	4	5	1	2	2	2	2	4	4	4
Participant 6	2	1	5	5	2	2	2	2	1	2	1	4	4	1	4	2	3	2	2	2	5	2	2	2	4	4
Participant 5	5	1	4	5	3	4	1	5	1	1	1	5	3	3	3	4	5	5	2	2	2	1	2	2	4	5
Participant 4	4	1	4	5	5	1	2	2	1	1	1	5	2	4	4	1	5	5	1	1	5	1	1	1	5	4
Participant 3	2	3	2	4	4	2	4	2	1	2	1	3	2	2	4	2	4	4	1	4	5	2	3	4	4	4
Participant 2	5	1	5	5	5	2	2	5	1	1	1	5	1	1	2	2	4	5	1	2	2	2	4	4	2	5
Participant 1	4	2	4	4	3	4	1	2	2	2	1	3	2	2	3	3	4	4	2	3	3	3	3	4	2	4

Audi A5

Road Type	Road Event 1 Small rubber bump													Road Event 2 Broken road												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	2	4	4	4	5	1	2	4	2	3	5	2	5	4	2	2	4	4	4	4	4	2	2	1	5	4
Participant 19	2	2	4	4	4	2	4	4	2	2	2	4	4	2	2	2	4	4	2	4	2	2	2	2	2	4
Participant 18	2	4	3	4	5	1	3	4	2	4	4	4	5	4	1	2	4	4	4	4	3	2	1	1	5	4
Participant 17	3	4	4	4	3	2	2	4	1	2	2	4	5	5	1	5	4	3	3	2	1	1	1	2	5	5
Participant 16	3	2	3	2	3	3	2	2	1	2	3	1	3	4	2	4	3	4	2	2	2	1	2	2	4	4
Participant 15	2	5	3	4	5	1	4	3	2	4	4	2	5	4	2	4	4	4	2	2	4	2	2	2	2	4
Participant 14	2	3	4	4	1	1	2	2	2	2	2	2	3	5	1	5	5	5	1	2	1	1	1	1	5	2
Participant 13	3	3	3	2	3	3	2	2	2	2	3	1	3	5	2	4	3	4	1	3	4	1	2	2	4	4
Participant 12	2	4	4	4	5	2	2	2	1	2	2	1	4	5	2	2	5	4	2	2	2	1	1	1	5	4
Participant 11	2	5	3	4	5	1	3	3	2	3	4	4	5	4	1	4	4	4	2	2	4	2	1	2	3	4
Participant 10	1	5	2	4	5	1	3	2	2	3	2	4	5	4	1	4	5	4	2	2	2	1	1	1	5	4
Participant 9	5	2	5	5	4	2	3	2	1	1	2	3	4	5	1	5	5	4	4	2	2	1	1	1	5	2
Participant 8	5	1	4	5	4	2	2	2	1	1	3	4	4	5	1	5	5	3	4	1	1	1	1	1	5	2
Participant 7	4	1	5	4	2	2	2	1	1	1	2	5	5	5	1	5	5	4	2	2	2	1	1	1	5	2
Participant 6	4	4	2	4	4	1	4	4	2	4	2	2	5	4	2	4	4	4	2	3	3	2	2	2	4	4
Participant 5	1	2	4	4	5	1	2	2	1	2	2	4	3	2	1	4	2	4	2	1	1	2	1	1	4	4
Participant 4	2	2	4	4	3	2	1	2	1	1	2	2	3	2	1	1	5	2	2	2	1	1	1	3	5	2
Participant 3	3	3	3	2	3	3	2	2	2	2	3	1	3	5	2	4	3	4	1	3	4	1	2	2	4	4
Participant 2	2	4	4	4	5	2	2	2	1	2	2	1	4	5	2	2	5	4	2	2	2	1	1	1	5	4
Participant 1	2	1	5	5	3	2	1	1	1	1	1	3	2	5	1	5	5	3	4	1	1	1	1	1	5	2

Road Type	Road Event 3 Country road													Road Event 4 Motorway												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	2	5	1	1	5	1	4	5	4	3	4	2	4	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 19	2	2	2	2	5	1	4	4	2	4	2	2	4	1	5	2	2	5	2	2	5	5	5	5	1	5
Participant 18	2	3	1	1	5	1	4	5	4	3	4	2	4	1	5	1	1	4	1	5	5	5	4	5	3	5
Participant 17	4	2	4	4	3	4	4	2	2	2	2	4	4	2	4	1	2	4	2	3	2	5	3	4	3	4
Participant 16	5	2	4	4	3	3	3	4	2	2	2	4	2	1	5	1	2	5	2	4	5	5	5	5	1	4
Participant 15	2	3	2	2	4	2	4	2	2	2	2	4	4	1	5	1	2	4	1	5	4	5	5	5	1	5
Participant 14	2	4	4	4	5	1	3	3	2	3	2	4	3	1	5	2	2	5	1	4	4	4	4	4	2	5
Participant 13	5	3	4	3	3	3	3	4	2	2	2	4	2	1	5	1	2	4	2	4	5	5	5	5	1	4
Participant 12	4	4	2	4	4	2	4	4	2	2	2	4	5	1	5	1	3	5	1	5	5	5	4	5	1	5
Participant 11	1	2	2	2	4	3	4	2	2	2	2	4	4	1	5	1	2	4	1	5	3	5	5	5	1	5
Participant 10	2	2	4	2	4	1	2	2	2	2	2	4	5	1	5	1	1	5	1	3	4	5	3	5	1	5
Participant 9	4	3	4	4	4	4	3	4	2	3	2	4	4	1	4	2	1	5	1	5	5	4	4	5	1	5
Participant 8	4	3	4	4	4	2	4	4	3	3	2	4	5	1	5	1	2	5	1	5	5	4	5	5	1	5
Participant 7	2	2	4	4	4	1	4	4	2	2	2	2	4	1	5	2	1	5	1	4	4	4	4	5	1	5
Participant 6	2	4	2	2	4	2	3	3	3	2	4	2	4	1	5	1	2	5	1	5	5	5	4	5	1	4
Participant 5	2	2	4	4	2	4	2	2	2	2	2	2	4	1	5	1	1	5	1	3	4	5	4	5	1	5
Participant 4	2	4	2	4	2	2	2	2	2	2	2	5	2	1	5	1	1	5	1	5	5	2	5	5	1	3
Participant 3	5	3	4	3	3	3	3	4	2	2	2	4	2	1	5	1	2	4	2	4	5	5	5	5	1	4
Participant 2	4	4	2	4	4	2	4	4	2	2	2	4	5	1	5	1	3	5	1	5	5	5	4	5	1	5
Participant 1	5	1	5	5	3	3	2	2	2	1	2	4	3	1	4	3	2	5	2	3	3	5	2	2	1	5

Road Type	Road Event 5 Rumble strips													Road Event 6 City Street												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	4	1	4	5	4	2	1	1	1	1	2	5	2	2	4	2	2	5	1	4	5	5	5	5	5	5
Participant 19	2	2	4	4	4	3	2	2	1	2	2	2	2	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 18	4	1	4	5	4	2	1	2	1	1	1	5	2	2	4	2	2	5	1	3	5	5	5	5	5	5
Participant 17	4	2	4	4	5	2	1	1	4	1	2	5	5	1	5	1	2	5	1	3	5	2	4	4	1	5
Participant 16	2	4	1	2	5	2	3	1	4	2	3	1	4	2	4	1	1	5	1	5	5	4	4	5	2	4
Participant 15	4	2	2	4	4	2	1	1	2	1	1	5	4	2	4	1	2	5	2	3	4	3	4	4	2	5
Participant 14	5	1	5	5	5	1	1	5	1	1	2	5	2	2	5	1	3	5	1	4	4	2	3	2	2	3
Participant 13	2	2	2	2	5	2	3	1	4	1	3	1	3	2	4	1	1	5	1	5	4	4	4	5	2	4
Participant 12	2	1	2	2	5	1	1	5	1	1	2	5	3	2	4	1	2	4	1	4	4	5	4	4	4	5
Participant 11	2	2	3	4	4	2	1	1	2	1	1	5	4	2	4	1	2	4	2	3	4	3	3	5	2	5
Participant 10	2	2	4	4	4	2	1	1	2	1	3	5	5	1	4	1	2	5	1	3	3	3	4	5	2	4
Participant 9	5	1	5	5	3	4	1	1	1	1	1	5	2	3	4	2	3	5	2	4	5	2	4	4	4	4
Participant 8	4	2	5	5	3	4	1	1	1	1	1	5	2	2	4	2	3	4	2	4	4	2	3	3	2	4
Participant 7	2	2	4	4	4	2	2	1	4	2	2	4	4	1	5	1	1	5	1	4	5	5	4	5	1	5
Participant 6	5	1	4	5	5	2	2	1	1	1	2	5	4	2	5	1	2	5	2	5	5	4	4	4	2	5
Participant 5	2	2	4	4	4	2	1	1	2	1	2	4	5	2	5	1	2	5	1	5	4	4	4	4	2	4
Participant 4	2	2	2	4	2	2	1	1	2	1	1	2	2	1	4	2	3	5	2	5	5	2	5	4	2	5
Participant 3	2	2	2	2	5	2	3	1	4	1	3	1	3	2	4	1	1	5	1	5	4	4	4	5	2	4
Participant 2	2	1	2	2	5	1	1	5	1	1	2	5	3	2	4	1	2	4	1	4	4	5	4	4	4	5
Participant 1	3	1	2	2	4	2	1	1	3	1	1	4	4	2	4	3	4	4	2	2	3	3	3	4	2	2

Road Type	Road Event 7 Cobblestone road													Road Event 8 Large bump												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 20	4	2	2	4	4	2	2	4	2	1	2	4	4	2	4	2	2	5	1	2	5	2	4	4	2	4
Participant 19	2	2	4	2	5	2	2	5	2	1	2	2	2	2	4	2	4	4	2	2	4	4	2	2	4	2
Participant 18	4	2	2	4	4	2	2	3	2	2	2	3	4	2	4	1	2	5	2	2	4	2	4	4	2	4
Participant 17	2	2	2	4	4	1	1	2	1	1	2	4	5	1	2	4	2	4	2	2	2	4	2	3	4	5
Participant 16	4	2	3	4	4	3	3	2	1	2	1	5	1	2	4	2	3	4	2	2	2	2	2	3	2	4
Participant 15	4	2	4	4	4	2	2	2	1	2	2	4	5	2	4	1	2	5	1	4	4	4	4	3	2	5
Participant 14	5	1	4	5	4	1	1	1	1	1	1	5	2	2	4	4	4	5	1	2	3	2	2	2	2	3
Participant 13	3	2	3	4	4	3	3	2	1	2	2	5	1	2	3	3	3	4	2	2	2	2	2	3	3	3
Participant 12	4	1	2	2	4	1	2	2	1	1	1	2	4	2	2	4	4	4	2	1	4	1	2	2	4	4
Participant 11	4	2	3	4	5	2	2	2	1	2	2	4	5	1	4	2	2	5	1	4	4	4	4	3	2	5
Participant 10	2	2	3	4	5	1	2	2	2	2	2	4	5	2	4	3	3	4	1	2	2	2	2	3	2	5
Participant 9	4	2	4	5	4	2	2	4	1	1	1	5	3	3	4	2	4	5	2	4	5	2	4	3	3	4
Participant 8	5	1	4	5	4	3	2	2	1	1	1	5	2	3	4	3	3	4	2	4	5	3	2	3	2	5
Participant 7	4	2	4	4	4	2	2	2	1	2	2	4	5	1	4	2	2	4	1	4	2	2	4	5	2	5
Participant 6	5	2	4	4	4	1	2	2	2	2	2	5	5	2	4	3	4	4	1	4	3	3	5	4	2	5
Participant 5	2	2	2	4	4	2	2	2	2	2	2	4	4	1	4	2	4	5	1	2	2	2	2	4	4	5
Participant 4	2	1	5	5	2	2	2	2	1	2	1	4	4	1	4	2	3	2	2	2	5	2	2	4	4	4
Participant 3	3	2	3	4	4	3	3	2	1	2	2	5	1	2	3	3	3	4	2	2	2	2	2	3	3	3
Participant 2	4	1	2	2	4	1	2	2	1	1	1	2	4	2	2	4	4	4	2	1	4	1	2	2	4	4
Participant 1	5	1	4	4	3	4	1	5	5	1	1	5	3	3	3	4	5	5	2	2	2	1	2	2	4	5

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Consent Form to Measure the Driver Subjective Response of Automotive Vibration Feedback

I. Introduction

Please carefully read the information below, which summarises the experiment that you are about to participate in. Please complete this form and indicate your agreement to participate in the study (if you choose to do so), by providing your signature and the date at the bottom of the consent certificate.

The purpose of this laboratory experiment is to measure the quality characteristics from the driver emotional experience of automotive steering wheel vibration. During the study you will be asked to rate your subjective response to various steering wheel vibration stimuli felt through the specially designed simulator, which will present actual road vibrations recorded from various automobiles. The laboratory equipment has been adjusted in accordance with the health and safety guidelines specified by British Standard 7085 Safety aspects of experiments in which people are exposed to mechanical vibration. This study has been approved by the research ethics committee of the School of Engineering and Design at Brunel University.

II. About this Laboratory-Study

This experiment will last approximately 50 minutes, in which time you will be exposed to a set of 30 various road type vibration stimuli recorded from actual automobile segments. You will be asked to rate each of the vibration stimuli using the rating scale displayed in front of you. The rating scale includes 14 descriptive pairs with a 5 point scale for each pair, so for example to respond to the first pair ('aggressive' or 'calm') you need to respond with either "extremely aggressive", "moderately aggressive", "neither", "moderately calm" or "extremely calm". All of the vibration signals must be rated using each of the 14 descriptive pairs.

While rating the vibration stimuli, when you reach half way down the rating scale, I will repeat the same vibration stimuli in order to refresh your memory of the stimuli in question. If necessary we can also pause the study if you need to take a longer time to respond to any descriptors.

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The results from this experiment will provide a better understanding of the semantic profiles of different automotive classes and the quality dimensions related to this driver vibration feedback, in turn establishing insights for automotive manufacturers and the measurement of the main dimensions used to define automotive vibration quality characteristics.

All of the information gathered from this laboratory experiment will be used for statistical analysis only and will remain strictly confidential.

III. Certificate of Consent

Measuring the Driver Vocabulary of Automotive Vibration Feedback

Please tick all the appropriate boxes

	YES	NO
I have read the Consent Form information sheets………………………….	☐	☐
I have had the opportunity to ask questions and discuss this study……	☐	☐
I have received satisfactory answers to all my questions………………..	☐	☐
I understand that my details will be kept confidential……………………..	☐	☐
I understand that I may withdraw from this study at any time………..….	☐	☐

I _________________________ (PRINT NAME HERE) give my consent to participate in this filed study and use my responses for research purposes only.

Signature: ______________________________

Date: __________/__________/__________

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IV. Participant Information

Full Name: ______________________________ Gender: Male ☐ Female ☐

Weight: _________________________________ Height: _________________________________

Age: ______________________________YEARS Occupation: ____________________________

Driving Experience: ________________YEARS Miles per Week: ____________________MILES

Nationality: _____________________________ Country of Origin: ______________________

Are you often exposed to vibrations, or do you regularly use vibration-producing tools as part of work or personal interest (i.e. tractors, drills, etc.)? YES ☐ NO ☐

If Yes, please specify: ____

Do you have any physical condition, which you feel may affect your vibration test responses?

YES ☐ NO ☐ If Yes, please specify: _____________________________

Did you consume alcohol or coffee in the last two hours before the study?

YES ☐ NO ☐ If Yes, please specify: _____________________________

What Type of vehicle do you regularly drive?

Car ☐ Van ☐ MPV ☐ Truck/Bus ☐ 4x4/SUV ☐

Your Vehicle Model: _____________________ Year of Registration: ___________________

V. Contact Details

For any further questions on this experiment or to find out the progress of the research project please contact: Arber Shabani / arber.shabani@brunel.ac.uk / Mob:07999 469 500

Supervised by : Marco Ajovalasit & Joseph Giacomin

Thank you for your Participation

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Appendix 11

Road Event 1

Road Type: 2 Passat - Broken Road	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	1	3	3	3	4	2	3	3	2	1	2	4	4
Participant 24	2	3	2	3	4	2	3	4	3	4	3	3	4
Participant 23	1	2	3	2	4	2	3	4	3	3	3	3	4
Participant 22	2	5	1	3	4	2	3	4	3	3	4	2	3
Participant 21	4	2	3	4	3	3	3	3	2	3	3	4	4
Participant 20	1	4	2	3	4	2	3	4	4	4	4	1	3
Participant 19	3	3	3	2	3	2	3	3	2	2	2	2	3
Participant 18	2	4	2	4	4	1	4	4	4	4	4	2	3
Participant 17	2	2	3	3	4	2	3	3	2	1	2	4	3
Participant 13	4	4	4	4	4	3	3	3	2	3	3	3	3
Participant 12	3	3	3	3	3	3	2	3	2	3	3	4	3
Participant 14	2	4	2	3	4	3	4	3	2	4	2	3	4
Participant 13	2	4	1	2	4	2	2	4	4	4	2	2	5
Participant 12	1	5	1	2	5	1	4	5	5	3	5	2	4
Participant 11	1	5	1	2	5	1	3	3	3	3	4	1	4
Participant 10	1	5	1	1	5	1	4	5	4	4	4	2	3
Participant 9	1	5	1	2	5	1	4	5	5	3	5	1	5
Participant 8	3	2	2	4	4	4	4	3	2	4	2	4	3
Participant 7	2	5	2	2	5	1	4	5	4	4	4	1	5
Participant 6	2	4	2	3	4	3	4	3	2	4	2	4	4
Participant 5	2	4	2	4	5	1	4	4	4	4	4	2	4
Participant 4	1	4	2	3	5	2	4	5	4	4	4	1	4
Participant 3	2	5	2	2	4	2	2	4	4	4	2	2	4
Participant 2	2	4	2	3	5	1	4	4	3	4	3	2	5
Participant 1	2	2	2	4	4	1	4	3	2	2	1	4	5

Road Event 2

Road Type: 5 E-Class - Rumble Strips	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	4	2	3	4	2	4	2	2	1	2	1	5	3
Participant 24	2	4	2	3	4	2	3	4	3	3	3	2	5
Participant 23	2	3	4	3	3	3	2	1	2	3	2	5	2
Participant 22	1	2	3	2	4	1	3	4	3	3	3	1	5
Participant 21	4	2	4	3	3	3	2	2	3	3	2	2	4
Participant 20	1	2	4	3	5	1	4	3	4	4	4	1	3
Participant 19	3	2	4	2	4	3	3	2	3	2	2	2	3
Participant 18	2	2	3	2	5	1	2	2	2	2	2	4	4
Participant 17	4	2	4	4	2	3	2	1	1	1	1	5	2
Participant 13	2	3	4	4	4	3	3	3	4	3	3	3	3
Participant 12	4	2	4	3	3	3	2	3	2	3	2	3	4
Participant 14	1	3	2	2	4	1	4	5	2	4	3	2	5
Participant 13	2	4	2	4	5	1	5	4	3	4	5	2	5
Participant 12	5	2	3	3	3	3	2	3	2	3	2	3	4
Participant 11	2	2	2	2	4	2	3	3	3	4	4	2	5
Participant 10	1	4	1	1	5	1	5	4	5	4	4	2	3
Participant 9	2	2	4	4	2	4	2	2	2	3	1	3	3
Participant 8	2	2	3	4	4	2	3	3	2	3	2	4	3
Participant 7	2	3	2	1	4	1	4	4	2	4	3	2	4
Participant 6	2	2	2	2	4	2	3	4	4	4	4	2	4
Participant 5	2	2	3	2	5	1	2	2	2	2	2	4	4
Participant 4	1	4	1	3	5	1	4	5	4	4	4	1	4
Participant 3	2	2	3	2	4	2	1	2	2	2	3	2	4
Participant 2	2	4	2	4	5	1	5	4	3	4	4	2	5
Participant 1	1	4	1	2	5	1	3	5	4	3	4	2	5

Road Event 3

Road Type: 3 Polo - Country Road	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	5	1	5	5	1	5	1	1	1	1	1	5	1
Participant 24	3	2	3	3	3	2	2	2	2	2	2	3	4
Participant 23	4	2	4	4	3	4	2	3	2	2	2	4	3
Participant 22	3	2	2	4	4	2	3	3	2	3	2	2	3
Participant 21	4	2	4	4	2	4	2	2	2	2	2	4	4
Participant 20	2	2	2	4	3	3	3	2	2	3	2	4	4
Participant 19	4	1	5	4	2	4	2	1	1	1	1	5	2
Participant 18	4	2	3	4	3	1	2	2	2	2	2	4	4
Participant 17	5	1	5	5	1	4	1	1	1	1	1	5	2
Participant 13	2	2	4	4	4	2	3	3	2	3	2	3	3
Participant 12	4	2	4	3	2	4	2	2	2	2	2	4	3
Participant 14	3	2	2	4	4	2	3	2	3	2	1	3	4
Participant 13	4	2	3	4	4	2	2	2	2	2	2	4	3
Participant 12	5	3	2	4	3	3	4	4	2	2	3	4	3
Participant 11	2	2	4	4	4	2	3	3	2	4	2	2	4
Participant 10	3	4	1	1	5	1	5	4	4	4	4	3	3
Participant 9	2	5	3	2	5	1	1	5	3	5	2	3	4
Participant 8	5	4	2	4	3	3	4	4	2	2	3	4	3
Participant 7	3	2	3	2	4	2	3	2	2	3	3	2	4
Participant 6	3	2	4	4	3	3	2	2	3	3	2	4	3
Participant 5	4	2	3	4	5	1	2	2	2	2	2	4	4
Participant 4	2	4	2	4	5	1	3	5	2	3	2	2	4
Participant 3	2	1	4	4	2	3	1	2	2	1	1	4	2
Participant 2	3	3	2	4	4	2	3	2	3	2	2	2	4
Participant 1	4	1	4	5	2	4	2	1	1	1	1	5	3

Road Event 4

Road Type: 1 Passat - Small Bump	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	1	4	2	1	4	1	4	4	4	4	4	2	5
Participant 24	1	5	1	1	5	1	4	5	5	5	5	2	4
Participant 23	1	5	1	2	5	2	3	5	5	5	5	1	4
Participant 22	1	5	2	2	5	1	5	4	5	5	4	1	5
Participant 21	1	5	1	1	5	1	4	5	5	4	5	3	4
Participant 20	1	4	2	1	5	1	5	5	4	5	5	1	4
Participant 19	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 18	1	5	1	2	5	1	5	5	5	4	4	1	5
Participant 17	1	4	2	1	5	1	4	5	4	4	5	1	5
Participant 13	1	5	1	2	5	1	3	5	4	4	5	1	5
Participant 12	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 14	1	5	1	1	5	1	5	4	5	4	5	1	5
Participant 13	1	4	1	1	5	1	5	5	5	5	5	1	4
Participant 12	1	5	2	2	5	1	4	5	4	5	5	1	5
Participant 11	1	5	1	1	5	1	5	5	2	4	4	1	4
Participant 10	4	5	1	3	2	3	5	2	5	5	5	5	1
Participant 9	1	5	1	1	5	1	3	5	5	5	5	1	4
Participant 8	2	5	2	3	5	2	5	4	4	4	4	2	4
Participant 7	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 6	1	5	1	1	5	1	5	5	5	4	5	1	4
Participant 5	1	5	1	3	5	1	5	5	5	4	4	1	5
Participant 4	1	4	2	1	5	1	5	5	4	5	5	2	5
Participant 3	1	5	1	1	5	1	1	5	4	4	5	2	5
Participant 2	1	5	1	2	5	1	5	5	4	5	4	1	5
Participant 1	1	5	1	2	5	1	3	5	4	4	4	1	5

Road Event 5

Road Type: 4 E-Class - Motorway	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	4	4	2	3	4	2	4	4	4	3	4	2	4
Participant 24	1	4	2	1	5	1	4	3	4	3	3	2	4
Participant 23	2	5	3	2	4	1	3	5	3	3	3	2	4
Participant 22	1	5	1	2	4	2	4	4	4	4	4	1	3
Participant 21	2	3	3	4	3	3	3	4	4	3	3	2	4
Participant 20	1	5	1	1	5	1	4	5	5	4	4	1	5
Participant 19	1	5	1	1	5	1	5	5	4	3	4	2	4
Participant 18	1	5	2	2	5	1	5	4	4	4	4	1	5
Participant 17	2	4	2	3	5	1	4	5	4	4	4	2	5
Participant 13	1	5	2	2	5	1	4	5	5	4	5	2	4
Participant 12	2	4	2	3	5	1	4	2	3	3	3	1	3
Participant 14	2	5	2	2	4	2	4	4	4	2	4	3	3
Participant 13	1	4	2	2	4	2	3	2	4	3	4	2	4
Participant 12	1	4	2	2	4	1	4	3	3	4	4	2	5
Participant 11	1	5	1	1	5	1	3	5	5	3	4	1	5
Participant 10	1	4	2	1	4	2	5	4	4	4	4	2	3
Participant 9	2	3	4	4	4	2	3	2	5	3	3	1	4
Participant 8	2	4	2	2	4	2	4	4	4	4	4	2	5
Participant 7	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 6	2	4	2	2	4	2	4	4	4	4	4	2	3
Participant 5	1	4	2	3	5	1	4	4	4	4	4	2	5
Participant 4	1	4	2	3	5	1	4	5	5	4	4	1	5
Participant 3	1	4	2	2	4	2	3	2	4	4	4	2	4
Participant 2	2	4	2	2	5	1	4	5	2	4	4	2	4
Participant 1	2	4	2	2	4	1	4	4	4	2	4	3	4

Road Event 6

Road Type: 3 Passat - Country Road	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	2	3	3	3	4	1	4	3	3	3	2	2	4
Participant 24	2	2	2	3	4	3	3	2	3	4	4	3	4
Participant 23	3	2	2	3	4	2	3	3	2	2	3	3	3
Participant 22	3	3	3	3	5	2	2	3	3	3	3	4	4
Participant 21	4	2	4	4	3	3	2	2	2	3	2	4	4
Participant 20	2	3	2	3	5	1	4	4	3	4	3	2	3
Participant 19	3	3	3	3	3	2	3	3	3	3	2	3	3
Participant 18	2	2	2	3	5	1	2	1	2	2	2	4	4
Participant 17	2	4	3	2	4	2	4	4	2	1	2	2	3
Participant 13	2	4	1	2	5	1	2	4	4	4	4	2	4
Participant 12	4	2	3	4	2	3	2	2	2	3	2	4	3
Participant 14	4	2	4	4	3	3	3	2	2	3	2	4	4
Participant 13	2	2	2	2	4	2	2	3	2	4	4	2	5
Participant 12	2	3	2	2	5	2	4	4	2	4	4	4	5
Participant 11	1	4	2	3	4	2	3	3	4	5	5	2	4
Participant 10	1	4	2	1	5	1	4	4	4	2	2	1	4
Participant 9	1	2	4	3	5	2	2	2	3	4	3	4	4
Participant 8	4	2	4	4	3	3	3	2	2	3	2	4	3
Participant 7	2	2	2	3	4	2	3	3	2	4	3	4	3
Participant 6	3	3	2	3	4	3	3	3	2	4	2	4	2
Participant 5	2	2	2	4	5	1	2	2	2	2	2	4	4
Participant 4	2	4	2	4	5	1	4	4	3	4	3	2	4
Participant 3	2	2	2	2	4	2	2	2	2	4	4	2	4
Participant 2	2	4	2	2	5	2	4	4	2	4	4	4	5
Participant 1	2	2	2	3	4	2	2	4	2	2	2	4	4

Road Event 7

Road Type: 2 Polo - Broken Road	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	3	2	3	3	3	3	2	3	2	2	2	4	4
Participant 24	1	3	3	2	4	2	3	3	2	2	2	2	4
Participant 23	4	2	4	4	4	4	3	2	1	3	1	3	3
Participant 22	2	5	2	3	4	2	4	4	2	3	3	3	4
Participant 21	4	2	3	3	3	3	3	3	2	3	2	4	4
Participant 20	1	2	4	3	4	1	4	3	3	3	2	2	3
Participant 19	4	3	4	3	3	3	3	3	3	2	2	3	3
Participant 18	2	2	3	3	4	1	2	2	2	2	2	4	3
Participant 17	4	1	4	4	3	4	2	2	1	2	1	4	3
Participant 13	2	4	2	2	5	2	4	5	4	3	4	2	3
Participant 12	4	2	3	3	2	4	2	4	1	2	2	4	2
Participant 14	1	3	2	3	5	1	4	4	3	3	2	1	5
Participant 13	1	1	2	2	4	2	4	3	2	2	2	4	5
Participant 12	2	4	2	2	5	2	4	5	4	3	4	2	4
Participant 11	1	4	2	2	4	2	3	3	5	3	3	1	4
Participant 10	2	3	2	2	4	1	4	3	2	4	4	2	4
Participant 9	2	1	4	4	3	2	2	2	2	2	1	3	5
Participant 8	4	3	4	3	3	2	4	3	2	3	2	4	3
Participant 7	1	2	2	2	4	1	4	3	2	2	3	4	5
Participant 6	2	2	3	4	4	3	3	2	2	3	2	4	3
Participant 5	2	3	2	3	5	1	2	2	2	2	2	4	4
Participant 4	1	3	2	3	5	1	4	4	3	3	2	2	5
Participant 3	2	1	4	4	2	3	2	1	2	1	2	2	3
Participant 2	2	3	4	4	4	2	3	2	2	2	2	4	4
Participant 1	4	1	4	2	2	4	2	2	1	2	1	4	4

Road Event 8

Road Type: 5 Passat - Rumble Strips	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	4	3	3	3	4	3	2	2	1	2	2	4	3
Participant 24	2	4	2	3	4	4	4	5	1	3	3	2	2
Participant 23	3	2	2	4	4	2	3	1	2	1	3	5	2
Participant 22	2	4	2	2	5	2	4	3	3	3	4	3	4
Participant 21	4	3	3	3	2	4	4	2	2	4	3	4	3
Participant 20	1	4	3	3	4	1	3	4	3	4	4	1	4
Participant 19	4	4	3	3	3	3	3	4	3	4	4	3	4
Participant 18	2	4	2	2	4	1	4	3	2	2	2	4	4
Participant 17	4	2	3	4	4	3	2	1	1	1	2	5	2
Participant 13	1	5	2	2	5	2	4	5	4	3	4	2	3
Participant 12	3	4	2	3	5	2	3	5	2	4	3	4	3
Participant 14	2	5	2	3	5	2	3	3	2	3	3	2	4
Participant 13	2	4	2	3	5	2	4	4	3	3	3	2	5
Participant 12	2	5	1	3	5	1	4	3	3	2	2	4	4
Participant 11	2	4	2	3	4	2	3	3	2	3	3	2	4
Participant 10	2	5	1	1	5	1	5	5	4	5	4	1	3
Participant 9	4	4	4	4	2	5	3	3	2	3	2	5	2
Participant 8	2	4	2	3	5	2	4	4	3	3	3	2	4
Participant 7	2	5	1	1	4	2	5	5	4	5	5	1	4
Participant 6	2	4	2	2	4	2	4	4	3	3	2	3	2
Participant 5	2	4	2	2	5	1	4	4	2	2	2	4	4
Participant 4	1	4	3	3	5	1	3	4	3	4	4	1	5
Participant 3	2	4	2	2	4	1	2	4	2	2	2	2	3
Participant 2	2	2	4	4	4	2	3	3	3	2	2	4	4
Participant 1	1	4	2	1	4	1	4	4	2	4	4	1	5

Road Event 9

Road Type: 4 Polo - Motorway	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	4	3	4	5	2	3	3	2	2	4	2	4	3
Participant 24	2	2	4	3	4	2	4	2	2	2	2	3	3
Participant 23	3	2	3	4	3	4	2	3	2	3	3	3	4
Participant 22	2	3	3	3	5	2	3	3	3	3	3	2	4
Participant 21	3	3	4	4	3	4	2	3	2	3	2	4	3
Participant 20	1	4	1	2	4	1	4	4	4	2	2	1	5
Participant 19	5	1	5	4	4	4	2	1	1	1	1	5	2
Participant 18	2	2	3	4	5	1	2	2	2	2	2	4	5
Participant 17	4	2	4	5	2	4	1	2	2	4	2	4	4
Participant 13	2	4	2	2	5	2	3	4	4	4	4	2	3
Participant 12	4	2	4	3	4	2	2	3	2	3	3	4	2
Participant 14	2	2	2	3	4	2	4	3	2	2	3	4	3
Participant 13	2	3	2	2	5	2	3	2	3	2	3	3	4
Participant 12	2	2	2	3	4	2	2	2	1	2	3	4	4
Participant 11	2	4	2	2	4	2	3	3	4	4	2	2	4
Participant 10	1	4	2	2	4	1	4	4	5	4	4	1	5
Participant 9	1	5	2	2	5	1	1	5	5	4	2	2	5
Participant 8	2	3	2	2	4	2	4	3	4	3	3	2	4
Participant 7	2	3	3	4	4	3	2	4	2	2	2	2	4
Participant 6	2	3	2	4	4	2	4	3	2	2	2	4	3
Participant 5	2	2	3	4	5	1	2	2	2	2	2	4	4
Participant 4	1	5	1	2	5	1	4	5	4	2	2	1	5
Participant 3	4	1	4	4	2	3	1	1	4	2	1	2	2
Participant 2	2	4	2	4	4	2	3	2	3	2	3	3	4
Participant 1	2	2	2	4	4	2	2	4	1	2	2	4	4

Road Event 10

Road Type: 1 E-Class - Small Bump	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	2	4	2	2	4	2	4	4	1	1	3	2	4
Participant 24	1	5	2	2	4	1	3	5	4	4	3	2	4
Participant 23	2	3	3	3	4	1	3	3	3	3	3	3	3
Participant 22	2	4	1	2	5	2	4	4	3	4	4	2	3
Participant 21	1	4	2	2	4	1	4	4	4	4	4	2	4
Participant 20	1	5	1	2	4	1	4	4	3	3	3	2	4
Participant 19	3	2	4	4	2	2	3	2	2	2	2	2	3
Participant 18	1	4	2	3	5	1	3	4	4	4	4	2	4
Participant 17	2	3	2	2	4	2	4	4	2	1	3	2	3
Participant 13	1	5	1	1	5	1	4	5	5	4	5	2	4
Participant 12	1	3	3	3	5	1	4	3	4	4	4	2	5
Participant 14	3	5	2	2	4	2	3	3	3	2	2	3	4
Participant 13	1	5	2	1	5	1	4	4	5	3	3	1	4
Participant 12	2	4	2	2	4	2	4	4	4	3	4	2	3
Participant 11	1	5	1	1	5	1	5	5	4	4	4	1	4
Participant 10	3	4	2	4	3	2	4	2	4	5	5	3	2
Participant 9	3	3	4	4	2	5	4	4	4	3	2	4	2
Participant 8	1	4	2	2	5	1	4	5	3	4	4	2	4
Participant 7	1	5	2	2	5	2	4	4	5	5	5	1	4
Participant 6	2	4	2	2	4	2	4	4	4	3	4	2	3
Participant 5	1	4	2	3	5	1	4	4	4	4	4	2	5
Participant 4	1	5	1	2	4	1	4	5	3	3	3	2	4
Participant 3	2	4	2	2	4	2	2	2	3	2	2	4	4
Participant 2	1	4	2	2	5	1	5	5	4	5	4	2	5
Participant 1	1	4	2	2	5	1	4	5	4	4	4	2	5

	Road Event 11												
Road Type	4 Passat - Motorway												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	1	5	2	1	5	1	4	5	4	5	2	2	4
Participant 24	1	5	1	2	4	2	4	5	5	5	5	1	5
Participant 23	2	4	3	2	4	2	3	4	5	4	3	3	4
Participant 22	1	5	1	1	5	2	5	5	5	5	4	1	4
Participant 21	1	4	2	2	4	2	4	4	4	4	4	3	4
Participant 20	1	4	1	1	5	1	4	5	4	4	4	1	5
Participant 19	3	3	3	3	3	3	3	3	3	3	4	3	3
Participant 18	1	4	2	3	5	1	3	2	2	4	4	2	4
Participant 17	1	4	2	1	4	1	4	5	4	4	2	2	4
Participant 13	1	5	1	2	5	1	4	5	5	5	5	1	4
Participant 12	1	5	2	2	5	1	5	5	5	5	5	1	5
Participant 14	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 13	1	5	1	1	5	1	5	5	5	4	5	1	5
Participant 12	1	5	1	2	4	2	4	4	4	5	4	2	4
Participant 11	1	5	1	3	5	1	5	5	5	5	5	1	5
Participant 10	4	5	2	4	2	3	5	2	5	5	5	1	2
Participant 9	1	5	1	1	5	1	3	5	5	5	4	1	4
Participant 8	1	5	2	3	5	2	5	5	5	3	4	2	4
Participant 7	1	5	2	1	4	2	4	4	4	4	4	1	4
Participant 6	1	5	1	1	5	1	4	5	4	4	4	2	3
Participant 5	1	4	2	3	5	1	4	2	2	3	4	2	4
Participant 4	1	5	1	1	5	1	4	5	4	4	3	1	5
Participant 3	2	4	3	2	4	2	2	2	2	4	2	2	4
Participant 2	1	5	1	1	5	1	5	5	4	4	5	1	5
Participant 1	1	5	1	1	5	1	3	5	4	5	5	1	5

	Road Event 12												
Road Type	1 Polo - Small Bump												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	4	2	3	4	3	2	3	3	2	2	3	4	3
Participant 24	3	2	3	4	3	3	1	2	1	2	2	4	3
Participant 23	3	3	3	3	3	3	4	2	2	2	2	3	2
Participant 22	3	2	4	4	2	2	2	2	2	3	2	4	4
Participant 21	4	2	4	4	2	4	2	2	2	3	2	4	2
Participant 20	4	2	4	5	4	3	2	2	2	1	1	4	3
Participant 19	4	1	4	4	2	4	2	1	1	2	1	5	1
Participant 18	3	2	3	4	5	3	2	2	2	2	2	3	3
Participant 17	4	2	3	4	4	2	4	2	2	2	3	4	3
Participant 13	2	4	2	3	4	2	4	4	2	2	2	4	3
Participant 12	4	2	4	3	2	4	2	2	1	2	2	5	2
Participant 14	1	2	2	3	4	1	4	3	1	3	4	2	4
Participant 13	3	2	3	3	5	1	2	2	2	2	2	4	3
Participant 12	3	3	2	4	2	3	3	4	1	2	2	3	2
Participant 11	1	5	2	1	4	1	4	5	2	3	4	2	4
Participant 10	1	2	1	1	5	1	2	3	3	3	2	2	5
Participant 9	5	1	4	5	2	4	2	2	1	1	1	5	4
Participant 8	4	3	4	4	2	4	3	4	2	2	2	5	2
Participant 7	3	2	3	3	3	3	2	1	1	2	1	4	2
Participant 6	3	3	4	3	3	3	3	2	2	2	2	5	3
Participant 5	3	2	3	4	5	1	2	2	2	2	2	4	4
Participant 4	4	1	4	5	4	3	2	2	2	1	1	4	4
Participant 3	5	1	5	5	1	5	1	1	1	2	1	2	2
Participant 2	2	2	2	4	4	2	3	4	3	3	4	2	4
Participant 1	5	1	5	5	4	2	1	1	1	1	1	5	4

	Road Event 13												
Road Type	3 E-Class - Country Road												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	2	3	4	4	2	3	2	4	1	2	2	5	4
Participant 24	3	3	2	3	5	2	2	2	3	4	2	3	3
Participant 23	3	2	3	3	4	2	2	3	2	2	2	3	3
Participant 22	3	3	3	2	4	2	3	3	3	2	2	3	2
Participant 21	4	2	4	4	2	4	2	2	2	3	2	4	2
Participant 20	3	3	3	3	3	2	3	4	3	4	2	3	4
Participant 19	5	1	5	5	1	5	1	1	1	1	1	5	2
Participant 18	3	1	2	3	4	1	2	2	2	2	2	3	3
Participant 17	2	2	4	4	2	3	2	4	2	1	2	5	3
Participant 13	2	4	1	3	4	2	3	4	2	2	2	3	3
Participant 12	4	2	3	3	2	4	2	2	1	3	3	4	2
Participant 14	1	2	2	2	4	1	3	3	2	2	2	1	4
Participant 13	3	2	3	2	5	2	3	3	4	4	2	2	3
Participant 12	2	3	4	4	4	2	4	2	3	4	3	1	3
Participant 11	2	4	2	3	4	1	4	4	4	4	5	2	4
Participant 10	1	3	2	3	5	3	1	3	3	3	3	2	5
Participant 9	3	4	3	2	5	1	3	3	4	4	2	2	4
Participant 8	4	2	4	4	3	4	3	4	2	3	2	4	3
Participant 7	3	2	4	4	4	2	2	2	2	2	2	4	3
Participant 6	3	4	3	4	4	3	3	4	2	2	2	2	3
Participant 5	2	1	2	4	5	1	2	2	2	2	2	4	4
Participant 4	2	3	3	3	4	2	3	4	3	4	2	3	4
Participant 3	4	1	4	4	2	4	1	1	1	1	2	1	2
Participant 2	2	3	2	4	4	2	4	2	3	4	3	2	4
Participant 1	1	4	2	2	4	1	3	4	2	2	2	2	4

	Road Event 14												
Road Type	5 Polo - Rumble Strips												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	4	1	5	5	1	4	1	1	1	1	1	5	1
Participant 24	3	3	4	3	3	3	2	3	3	3	2	3	3
Participant 23	3	2	3	3	2	3	2	2	2	2	2	3	2
Participant 22	4	1	5	4	1	4	1	1	2	2	2	3	1
Participant 21	4	1	4	4	3	3	2	3	2	2	1	2	2
Participant 20	3	2	3	4	4	3	2	3	2	2	2	1	4
Participant 19	5	1	5	5	1	5	1	1	2	2	2	5	2
Participant 18	3	1	4	5	4	1	1	1	1	1	1	5	3
Participant 17	4	1	5	5	1	4	1	1	1	1	2	5	2
Participant 13	2	4	3	3	4	2	3	4	3	3	3	2	3
Participant 12	4	1	4	4	2	4	1	2	2	2	1	2	2
Participant 14	4	1	5	5	4	3	2	2	2	4	1	2	3
Participant 13	4	1	4	3	2	2	2	2	4	1	2	4	2
Participant 12	3	2	4	4	4	2	2	1	2	3	2	2	4
Participant 11	1	4	1	1	5	1	3	5	5	4	4	1	4
Participant 10	2	2	3	2	4	2	2	2	2	1	1	4	3
Participant 9	4	2	5	5	4	3	2	2	2	4	1	2	4
Participant 8	4	2	4	3	2	2	2	2	4	1	2	4	2
Participant 7	2	2	2	2	4	3	2	2	1	2	1	2	4
Participant 6	4	2	4	5	2	4	3	2	3	4	2	2	2
Participant 5	4	1	5	5	4	1	1	1	1	1	1	5	3
Participant 4	2	2	3	4	4	3	2	3	2	2	2	2	4
Participant 3	4	1	4	4	2	4	1	1	2	1	2	4	2
Participant 2	2	2	4	4	4	2	2	2	2	3	2	2	4
Participant 1	5	1	5	5	2	4	1	1	1	1	1	5	2

	Road Event 15												
Road Type	2 E-Class - Broken Road												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	4	2	4	4	5	3	2	3	1	1	2	4	3
Participant 24	4	3	4	4	3	3	4	2	3	3	2	4	4
Participant 23	3	3	3	3	3	2	3	4	2	2	2	3	1
Participant 22	3	2	4	4	2	3	3	1	2	4	2	4	3
Participant 21	4	3	4	4	2	4	2	2	2	3	2	4	3
Participant 20	3	2	3	3	3	2	2	3	2	3	2	2	3
Participant 19	5	1	4	2	2	3	2	1	2	3	2	4	3
Participant 18	4	2	4	4	3	2	2	1	1	2	2	5	3
Participant 17	4	2	4	4	4	3	2	4	1	1	2	4	1
Participant 13	2	4	2	4	4	2	3	4	2	4	2	4	4
Participant 12	4	2	5	5	2	4	2	2	1	1	2	5	2
Participant 14	4	1	4	3	2	3	2	1	2	1	2	4	2
Participant 13	2	2	3	4	3	2	3	2	3	2	2	2	3
Participant 12	3	2	4	4	2	2	3	2	1	2	2	5	3
Participant 11	4	2	4	3	3	4	3	3	2	2	2	4	3
Participant 10	3	2	4	3	3	3	3	2	3	2	2	3	2
Participant 9	4	4	2	2	5	1	4	4	4	4	2	2	4
Participant 8	3	2	4	4	2	4	3	2	2	3	2	5	3
Participant 7	4	2	4	4	3	4	2	2	2	2	1	5	2
Participant 6	4	3	4	4	3	3	3	2	2	3	2	4	3
Participant 5	4	1	4	5	4	1	2	1	1	2	2	5	4
Participant 4	3	2	3	4	4	2	2	3	2	3	3	2	4
Participant 3	4	1	4	3	2	3	2	1	2	1	2	4	2
Participant 2	2	3	3	4	4	2	3	2	3	2	2	2	5
Participant 1	2	4	2	2	4	2	2	2	2	4	2	2	5

	Road Event 16												
Road Type	4 E-Class - Motorway												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	1	4	2	2	5	1	4	5	4	5	4	2	4
Participant 24	2	5	2	2	4	2	3	5	4	4	4	3	3
Participant 23	2	4	1	3	4	2	4	4	3	4	4	1	4
Participant 22	2	5	1	2	4	1	4	4	4	5	4	2	4
Participant 21	2	4	2	1	5	1	2	4	3	3	3	4	4
Participant 20	1	4	1	2	4	1	4	4	5	4	4	1	4
Participant 19	2	3	2	2	4	2	4	4	4	4	4	2	4
Participant 18	2	4	2	2	4	1	3	5	2	4	4	3	4
Participant 17	2	4	1	2	5	1	4	4	4	5	4	2	5
Participant 13	2	4	1	2	5	1	4	5	4	4	4	2	5
Participant 12	1	5	1	2	5	1	5	5	5	4	4	1	5
Participant 14	2	4	2	2	4	2	4	4	4	4	4	1	5
Participant 13	2	5	2	2	4	2	2	5	4	4	4	2	4
Participant 12	2	5	2	3	2	3	5	4	4	4	5	3	5
Participant 11	1	5	1	1	5	1	3	5	5	5	4	1	3
Participant 10	4	5	2	4	2	3	5	3	4	4	3	3	3
Participant 9	1	5	1	1	5	1	3	5	5	5	5	1	5
Participant 8	2	5	2	2	5	2	4	4	4	4	4	1	4
Participant 7	1	4	1	1	5	1	5	5	5	5	5	1	5
Participant 6	2	4	2	2	4	2	4	4	4	4	4	1	3
Participant 5	2	4	2	2	5	1	4	4	2	4	4	4	4
Participant 4	1	5	1	2	5	1	5	5	5	4	4	1	5
Participant 3	2	5	2	2	4	2	2	2	4	4	4	2	4
Participant 2	2	4	2	4	5	2	4	4	4	4	4	2	5
Participant 1	1	5	1	1	5	1	4	5	4	4	4	1	5

	Road Event 17												
Road Type	2 Polo - Broken Road												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	2	3	3	4	4	3	2	2	2	3	2	3	3
Participant 24	2	4	3	3	4	2	2	3	2	2	2	3	3
Participant 23	3	2	3	3	3	4	1	2	1	3	3	4	4
Participant 22	2	2	4	3	4	2	2	3	2	3	1	3	4
Participant 21	4	2	4	4	2	4	2	2	2	3	2	4	4
Participant 20	2	2	3	3	3	3	2	2	2	2	1	4	3
Participant 19	4	2	4	3	2	3	2	2	1	2	2	5	3
Participant 18	3	2	3	3	4	1	2	2	2	2	2	3	4
Participant 17	3	2	4	5	4	4	2	2	1	1	2	4	3
Participant 13	2	3	3	4	4	2	2	4	2	3	2	4	3
Participant 12	3	2	4	3	3	3	2	2	1	3	2	4	3
Participant 14	2	2	2	2	4	2	2	2	2	4	4	2	2
Participant 13	2	2	2	4	4	2	3	3	2	3	2	3	2
Participant 12	1	2	2	1	5	1	2	2	2	2	2	3	3
Participant 11	2	5	2	2	4	3	3	4	4	4	5	1	3
Participant 10	1	3	2	1	5	1	3	3	3	2	2	3	5
Participant 9	2	2	4	4	5	3	2	2	2	4	2	1	5
Participant 8	4	4	4	4	4	3	4	4	2	3	2	4	4
Participant 7	2	3	4	4	5	2	3	2	2	4	2	2	3
Participant 6	2	4	2	2	4	2	4	4	2	2	2	4	4
Participant 5	3	2	4	4	5	1	2	2	2	2	2	4	4
Participant 4	4	1	5	4	3	3	2	2	2	1	1	4	3
Participant 3	2	2	2	2	4	2	2	2	2	4	4	2	2
Participant 2	2	3	2	4	4	2	3	3	2	3	2	3	4
Participant 1	2	2	2	4	4	2	2	2	2	2	2	4	4

	Road Event 18												
Road Type	5 Passat - Rumble Strips												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	3	3	3	4	2	4	1	2	1	2	2	4	3
Participant 24	2	2	3	3	4	2	3	2	3	3	3	3	5
Participant 23	3	4	4	3	4	3	3	2	3	3	3	2	2
Participant 22	1	4	2	3	5	2	3	4	3	3	3	3	5
Participant 21	3	4	3	3	4	2	4	4	3	2	3	3	3
Participant 20	1	3	2	2	4	2	4	5	4	3	3	2	3
Participant 19	3	3	4	3	3	3	3	3	4	4	4	2	4
Participant 18	3	3	2	3	4	2	2	2	2	2	2	3	3
Participant 17	4	2	4	4	2	4	1	1	1	1	2	4	2
Participant 13	1	4	2	3	4	2	3	4	5	4	4	2	3
Participant 12	3	4	1	2	5	1	4	4	3	3	3	4	4
Participant 14	3	3	2	5	4	2	2	2	2	2	2	4	4
Participant 13	2	3	5	2	4	1	4	2	4	3	3	2	3
Participant 12	3	4	3	3	4	2	4	4	3	2	3	3	3
Participant 11	2	5	1	3	5	1	3	5	4	4	4	2	3
Participant 10	1	3	3	1	5	1	2	3	2	3	3	2	3
Participant 9	2	3	4	4	2	4	2	2	4	4	4	2	4
Participant 8	5	4	2	3	5	2	4	4	4	4	4	2	4
Participant 7	2	4	2	1	4	4	4	4	4	4	4	2	4
Participant 6	2	5	2	2	5	1	4	5	4	2	3	2	3
Participant 5	3	3	2	5	4	1	2	2	2	2	2	4	4
Participant 4	1	5	2	2	4	1	4	5	4	3	3	2	4
Participant 3	2	4	2	2	4	2	2	4	2	2	4	2	4
Participant 2	2	4	2	4	5	2	4	4	3	4	3	3	4
Participant 1	1	4	1	2	5	5	4	4	4	2	4	2	4

	Road Event 19												
Road Type	3 Polo - Country Road												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	4	2	4	5	2	3	2	2	2	2	2	4	2
Participant 24	4	2	4	4	3	2	2	1	1	2	2	4	2
Participant 23	3	1	4	4	3	5	2	2	1	1	1	5	3
Participant 22	4	1	5	4	2	3	2	2	2	3	2	4	3
Participant 21	4	1	3	5	1	5	1	1	2	3	2	4	2
Participant 20	2	1	4	4	3	2	2	2	1	2	2	4	3
Participant 19	5	1	5	5	1	5	1	1	1	2	1	5	4
Participant 18	5	1	5	4	2	2	1	1	1	2	1	4	3
Participant 17	5	1	5	5	2	4	1	2	1	1	2	5	3
Participant 13	3	2	4	4	3	2	2	3	2	2	2	4	3
Participant 12	5	1	5	5	2	4	1	2	1	2	1	5	2
Participant 14	2	1	4	5	4	2	3	2	1	3	2	4	2
Participant 13	3	2	4	4	3	2	2	1	2	2	2	4	2
Participant 12	5	1	5	5	2	3	1	1	1	1	1	5	2
Participant 11	2	2	2	2	3	2	2	4	4	4	4	2	2
Participant 10	1	1	3	1	5	1	2	3	2	2	2	2	5
Participant 9	2	2	4	4	5	2	1	2	2	4	2	1	4
Participant 8	5	1	4	4	2	4	2	2	2	2	2	5	2
Participant 7	5	2	4	5	2	4	1	1	1	2	1	5	3
Participant 6	3	2	4	4	4	2	2	2	2	4	2	4	3
Participant 5	5	1	5	4	2	1	1	1	1	1	1	5	4
Participant 4	2	3	4	4	4	2	2	3	1	2	2	4	4
Participant 3	4	1	4	5	2	4	1	1	1	1	1	5	1
Participant 2	2	2	4	4	4	2	3	2	2	3	2	3	4
Participant 1	5	1	5	5	2	2	1	1	1	1	1	5	2

	Road Event 20												
Road Type	1 Passat - Small Bump												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	1	4	2	2	5	1	4	4	4	3	4	2	1
Participant 24	2	5	1	2	4	2	4	5	2	5	4	2	3
Participant 23	1	5	1	1	5	2	5	5	4	4	4	1	3
Participant 22	2	5	1	2	5	2	4	5	4	5	4	2	5
Participant 21	2	5	1	2	4	4	4	5	3	5	5	2	3
Participant 20	1	4	1	2	5	1	2	5	4	5	4	1	3
Participant 19	2	5	1	1	5	1	5	5	4	4	3	1	2
Participant 18	1	5	1	2	5	1	5	4	4	4	4	2	4
Participant 17	2	4	2	2	5	2	4	5	4	3	4	2	4
Participant 13	1	5	1	1	5	1	4	5	5	5	5	2	4
Participant 12	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 14	2	4	1	1	5	1	5	5	3	4	3	1	3
Participant 13	1	4	2	3	5	1	5	4	2	4	4	2	4
Participant 12	2	4	1	2	4	2	4	5	3	5	5	2	3
Participant 11	2	5	3	2	4	3	2	5	4	3	3	2	4
Participant 10	5	5	3	5	1	5	5	5	5	5	5	1	1
Participant 9	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 8	1	5	1	2	5	1	5	5	5	5	4	2	4
Participant 7	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 6	1	5	1	2	5	1	5	5	4	4	4	2	4
Participant 5	1	5	1	3	5	1	5	4	4	4	4	2	4
Participant 4	1	5	1	2	5	1	2	5	4	5	5	1	5
Participant 3	1	5	2	2	4	2	2	4	4	4	4	2	4
Participant 2	1	5	2	4	5	1	4	4	4	5	4	2	5
Participant 1	1	5	1	1	5	1	4	5	4	4	5	1	5

Road Type	Road Event 21 5 E-Class - Rumble Strips												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	3	2	4	4	2	3	1	2	2	2	2	3	3
Participant 24	2	3	3	3	4	2	2	2	3	3	3	3	4
Participant 23	2	2	3	3	4	4	2	3	3	3	3	3	4
Participant 22	3	2	2	3	4	2	2	3	2	2	2	4	3
Participant 21	4	2	4	4	4	3	2	3	4	1	2	2	3
Participant 20	2	2	3	3	3	2	3	4	3	3	2	2	3
Participant 19	3	2	4	4	2	3	2	2	2	4	2	4	3
Participant 18	3	2	3	4	4	1	2	2	1	2	1	4	3
Participant 17	3	1	4	5	2	4	1	1	1	1	2	4	2
Participant 13	3	3	2	4	4	2	3	3	3	2	2	2	3
Participant 12	4	2	2	3	4	3	2	2	2	3	3	3	4
Participant 14	2	1	4	4	2	1	2	1	2	2	4	4	2
Participant 13	3	2	3	4	4	2	2	2	3	2	2	3	3
Participant 12	2	2	2	2	3	2	1	1	4	2	2	2	4
Participant 11	2	4	2	3	3	2	2	4	5	4	3	1	4
Participant 10	1	2	3	1	5	1	1	3	2	2	2	2	5
Participant 9	2	4	2	2	5	2	1	2	4	3	2	2	5
Participant 8	2	3	2	4	4	3	4	3	2	3	3	2	4
Participant 7	1	4	2	2	5	1	5	4	5	5	5	1	4
Participant 6	3	2	3	4	4	2	3	3	3	3	3	2	3
Participant 5	4	2	5	4	5	1	2	2	1	2	1	5	4
Participant 4	2	3	3	4	4	2	4	4	3	3	2	2	4
Participant 3	2	1	4	4	2	1	2	1	2	2	4	4	2
Participant 2	2	2	3	4	4	2	3	2	3	2	2	3	4
Participant 1	2	1	4	4	4	2	2	2	2	2	2	4	4

Road Type	Road Event 22 4 Polo - Motorway												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	3	3	3	4	3	3	2	3	3	3	2	3	3
Participant 24	2	3	3	4	4	2	3	4	2	2	2	2	3
Participant 23	4	2	3	3	4	3	3	3	3	3	2	3	4
Participant 22	2	3	3	3	3	2	2	3	2	3	3	3	4
Participant 21	4	2	3	4	3	3	2	3	2	2	2	4	2
Participant 20	2	3	3	3	4	1	3	4	2	4	2	3	4
Participant 19	4	3	3	4	3	3	3	2	2	2	2	4	4
Participant 18	4	3	4	3	4	1	2	2	2	1	1	4	3
Participant 17	4	2	4	5	2	3	2	3	3	4	2	4	4
Participant 13	2	3	2	4	4	2	3	3	2	2	2	4	4
Participant 12	3	3	3	3	4	3	2	3	2	3	2	4	4
Participant 14	2	4	2	3	4	2	4	4	2	4	2	2	4
Participant 13	1	4	2	4	5	1	3	2	4	3	3	2	5
Participant 12	4	5	3	4	5	1	2	5	4	4	2	4	4
Participant 11	2	3	2	2	4	1	3	3	2	3	3	2	4
Participant 10	1	2	2	3	2	3	3	2	2	2	2	2	3
Participant 9	2	5	2	2	5	2	4	4	4	3	2	2	4
Participant 8	2	4	2	3	4	2	4	4	2	4	3	2	4
Participant 7	1	4	2	2	5	1	2	2	4	3	3	2	5
Participant 6	2	4	2	2	4	2	4	4	2	2	2	4	3
Participant 5	4	2	4	4	5	1	2	2	2	1	1	4	4
Participant 4	2	2	4	3	4	1	2	4	2	4	2	2	4
Participant 3	2	1	4	5	2	2	2	1	1	1	2	2	2
Participant 2	2	3	2	4	4	2	4	3	3	3	3	2	4
Participant 1	4	1	4	4	2	4	1	1	1	2	2	1	4

Road Type	Road Event 23 3 E-Class - Country Road												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	2	3	3	2	4	2	3	3	3	3	2	3	3
Participant 24	2	2	2	3	4	3	3	3	3	3	3	2	3
Participant 23	3	2	3	3	4	3	2	3	2	3	3	3	3
Participant 22	2	3	3	2	3	2	3	4	3	2	3	3	4
Participant 21	3	2	4	4	3	4	2	3	2	4	2	4	3
Participant 20	1	3	2	3	3	1	3	4	3	3	2	2	4
Participant 19	4	3	4	4	3	4	2	3	2	2	2	4	4
Participant 18	3	2	4	4	5	1	2	2	2	2	1	5	4
Participant 17	2	3	3	2	4	2	3	4	2	3	2	3	4
Participant 13	3	2	3	4	4	2	2	3	2	2	2	4	4
Participant 12	4	2	3	4	3	3	2	2	2	3	3	4	3
Participant 14	2	2	4	4	2	2	2	2	1	2	1	2	2
Participant 13	2	4	2	2	5	1	4	4	5	4	4	1	4
Participant 12	2	2	3	2	4	1	2	3	3	4	4	2	4
Participant 11	2	4	2	2	4	2	3	4	4	3	4	2	3
Participant 10	1	2	1	1	5	1	2	4	2	3	2	2	5
Participant 9	1	4	2	2	5	1	4	4	5	4	4	1	4
Participant 8	4	2	4	4	3	4	3	2	2	3	2	4	2
Participant 7	1	4	2	1	5	1	4	4	4	3	4	2	4
Participant 6	2	4	2	2	4	2	4	4	2	3	2	4	3
Participant 5	4	2	4	4	5	1	2	2	1	1	1	5	4
Participant 4	1	4	2	3	5	1	5	4	3	3	2	2	4
Participant 3	2	2	4	4	2	2	2	2	1	2	1	2	2
Participant 2	2	4	2	2	4	1	4	4	3	4	4	2	5
Participant 1	2	2	2	4	4	2	2	2	2	2	2	4	4

Road Type	Road Event 24 1 Polo - Small Bump												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	2	2	3	4	3	3	3	3	3	2	2	4	3
Participant 24	3	3	4	4	4	3	2	2	2	2	2	4	3
Participant 23	3	3	4	3	4	3	3	3	1	2	3	3	4
Participant 22	3	3	3	4	3	4	3	3	2	3	2	4	4
Participant 21	3	4	2	2	4	3	4	4	3	3	3	3	3
Participant 20	1	2	3	3	3	2	2	2	2	2	2	3	3
Participant 19	5	1	5	5	2	5	1	1	1	1	1	5	5
Participant 18	4	3	4	4	4	4	3	2	1	1	2	4	4
Participant 17	2	2	3	4	4	2	3	4	2	1	2	4	3
Participant 13	3	4	4	4	4	2	3	4	1	2	2	5	3
Participant 12	4	3	4	4	3	3	3	3	2	2	2	5	3
Participant 14	4	2	4	3	5	4	2	2	1	1	2	4	4
Participant 13	4	1	4	5	2	5	1	1	1	1	1	5	5
Participant 12	3	3	2	4	5	1	4	3	4	2	4	2	5
Participant 11	2	4	4	4	4	3	3	2	4	3	4	2	4
Participant 10	2	2	2	1	4	1	2	3	2	3	3	4	4
Participant 9	4	2	4	4	2	4	2	2	1	2	1	5	3
Participant 8	4	5	2	4	2	4	4	4	2	2	3	5	3
Participant 7	2	5	4	4	4	3	3	3	2	1	2	5	3
Participant 6	2	3	4	4	3	2	3	2	2	2	3	5	3
Participant 5	4	2	4	3	5	4	2	2	1	2	2	4	4
Participant 4	1	2	3	3	4	2	2	2	2	2	2	2	4
Participant 3	5	1	5	5	1	5	1	1	1	1	1	3	1
Participant 2	2	4	2	4	5	1	4	4	4	4	4	2	5
Participant 1	4	2	4	5	4	2	2	2	1	1	1	2	4

Road Type	Road Event 25 2 Passat - Broken Road												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	2	3	3	4	4	2	2	3	2	2	2	3	3
Participant 24	2	4	2	3	4	2	4	4	3	2	3	3	4
Participant 23	2	4	3	3	3	2	3	4	3	2	2	2	4
Participant 22	2	3	3	3	4	3	3	3	3	3	3	3	3
Participant 21	3	2	3	3	3	3	2	3	3	3	3	3	4
Participant 20	2	3	3	3	4	2	2	3	3	3	3	3	3
Participant 19	3	2	4	3	2	4	2	2	2	3	2	2	3
Participant 18	2	3	2	2	4	2	4	4	3	4	3	2	4
Participant 17	2	2	4	4	3	2	2	3	2	2	1	4	3
Participant 13	3	5	2	4	4	2	4	5	2	2	2	4	4
Participant 12	3	3	3	3	5	2	3	3	2	3	2	4	3
Participant 14	2	2	4	4	4	4	3	2	1	4	2	2	4
Participant 13	2	3	2	3	4	1	4	4	3	4	3	2	4
Participant 12	3	3	3	4	4	2	4	4	2	2	2	4	3
Participant 11	1	5	1	3	5	1	3	5	5	3	3	1	5
Participant 10	2	3	2	2	4	2	2	3	2	2	1	2	3
Participant 9	2	4	4	4	4	4	3	2	4	4	2	2	5
Participant 8	2	3	2	3	5	2	4	4	4	3	4	2	3
Participant 7	1	4	2	2	5	1	4	4	4	4	4	2	4
Participant 6	3	3	3	4	4	2	4	4	2	4	2	4	3
Participant 5	2	4	2	2	5	2	4	4	4	4	4	2	4
Participant 4	2	4	3	3	4	2	2	4	3	3	3	2	5
Participant 3	3	2	4	4	2	4	2	2	2	2	1	2	2
Participant 2	2	4	2	3	4	1	4	4	3	4	3	2	4
Participant 1	4	1	2	5	4	4	2	4	2	2	2	4	4

Road Type	Road Event 26 1 E-Class - Small Bump												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	2	4	2	2	4	2	3	4	2	2	4	4	3
Participant 24	2	4	2	3	5	1	4	3	4	5	4	2	4
Participant 23	2	3	2	2	5	1	4	4	3	4	3	2	4
Participant 22	2	4	2	2	4	2	4	4	4	4	4	2	3
Participant 21	2	4	2	3	3	3	3	3	4	4	3	3	4
Participant 20	1	4	1	1	4	1	4	3	5	4	4	1	3
Participant 19	1	4	2	2	4	2	4	4	5	4	4	1	2
Participant 18	2	3	2	3	4	1	4	4	2	4	4	2	3
Participant 17	2	4	2	2	4	2	3	5	2	2	3	4	4
Participant 13	2	5	1	2	5	1	4	5	2	4	4	2	4
Participant 12	1	5	1	2	5	1	5	5	4	5	4	2	4
Participant 14	4	2	4	4	4	3	4	2	4	4	2	1	4
Participant 13	1	3	1	3	5	1	5	3	5	4	4	1	5
Participant 12	1	4	2	2	5	1	5	5	4	4	4	2	3
Participant 11	1	5	2	2	3	1	5	5	5	5	5	1	5
Participant 10	4	4	2	4	2	4	4	2	4	5	5	3	1
Participant 9	4	2	4	4	4	4	4	2	4	4	2	1	4
Participant 8	2	5	2	2	5	2	4	4	4	4	4	2	5
Participant 7	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 6	2	4	1	2	5	1	4	5	4	4	4	2	4
Participant 5	2	4	2	3	5	1	4	4	2	4	4	4	2
Participant 4	1	5	1	1	5	1	5	5	5	4	4	1	5
Participant 3	2	2	2	2	4	1	2	2	2	2	2	2	4
Participant 2	1	4	2	2	5	1	5	5	4	4	4	2	5
Participant 1	1	4	2	2	4	2	4	4	4	4	4	2	5

Road Type	Road Event 27 3 Passat - Country Road												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	2	3	3	3	3	2	3	3	2	3	2	3	4
Participant 24	2	3	3	3	4	2	3	2	3	4	3	3	4
Participant 23	3	4	3	4	4	2	4	4	3	3	3	3	3
Participant 22	2	3	2	3	3	1	3	3	2	3	2	2	4
Participant 21	3	2	4	4	4	3	2	4	3	3	2	3	3
Participant 20	2	3	2	3	4	1	4	4	2	2	3	2	3
Participant 19	4	2	4	4	2	3	2	2	2	2	2	4	4
Participant 18	3	2	4	4	3	1	2	2	3	3	2	4	4
Participant 17	2	3	2	3	3	3	2	4	2	3	2	4	3
Participant 13	2	4	2	4	4	1	4	4	5	4	4	1	3
Participant 12	3	2	3	3	4	2	2	2	2	3	3	4	4
Participant 14	1	3	2	1	4	1	3	4	3	4	4	1	4
Participant 13	4	2	4	4	2	3	2	2	2	2	2	4	3
Participant 12	2	2	4	4	3	2	4	2	2	2	2	4	3
Participant 11	2	4	3	3	5	2	4	4	4	4	4	2	4
Participant 10	3	4	2	3	3	3	3	4	3	3	2	3	2
Participant 9	1	5	2	2	5	1	5	5	5	5	5	1	5
Participant 8	2	3	4	4	2	2	4	4	2	4	2	4	4
Participant 7	1	4	2	1	4	1	5	4	5	4	4	1	4
Participant 6	2	4	2	2	4	2	4	4	2	2	2	4	3
Participant 5	3	2	4	4	5	1	2	2	2	2	2	4	4
Participant 4	2	4	2	3	5	1	4	4	2	2	3	2	5
Participant 3	2	4	2	2	4	2	2	4	2	4	4	2	4
Participant 2	2	4	2	4	5	1	4	5	3	4	2	3	4
Participant 1	4	1	4	5	2	4	1	1	1	2	2	5	2

Road Type	Road Event 28 2 E-Class - Broken Road												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	3	2	3	3	3	2	2	2	2	2	2	4	4
Participant 24	3	2	4	4	3	3	3	2	2	2	2	4	4
Participant 23	4	3	4	4	4	3	3	3	1	2	2	5	3
Participant 22	3	2	3	4	3	3	4	2	2	1	3	4	3
Participant 21	4	2	4	4	2	4	2	2	2	2	2	4	2
Participant 20	4	2	3	4	2	3	2	2	1	1	2	4	2
Participant 19	4	2	4	3	2	3	2	2	1	1	1	5	4
Participant 18	3	2	3	3	3	2	1	2	2	2	2	4	4
Participant 17	3	2	4	4	3	2	2	2	1	2	1	5	3
Participant 13	3	3	2	3	4	2	3	3	2	2	2	4	3
Participant 12	4	2	4	4	2	4	2	2	1	2	2	5	3
Participant 14	2	2	2	4	3	2	3	2	2	1	2	4	3
Participant 13	2	3	2	3	4	2	4	3	2	3	3	2	2
Participant 12	4	2	4	4	3	3	2	2	2	2	3	5	2
Participant 11	2	2	2	4	3	2	3	3	1	1	2	4	4
Participant 10	1	2	2	1	5	1	3	3	2	2	2	2	5
Participant 9	2	2	4	4	2	4	2	2	2	2	2	4	3
Participant 8	4	2	4	4	2	4	2	2	1	3	2	5	2
Participant 7	2	1	1	4	4	2	4	2	2	3	3	4	2
Participant 6	4	2	4	4	3	3	2	2	2	2	3	5	4
Participant 5	4	1	4	4	5	1	1	1	1	1	1	5	4
Participant 4	4	1	4	4	2	3	1	2	1	1	1	5	2
Participant 3	5	1	5	5	1	5	1	1	1	1	1	5	1
Participant 2	2	3	2	4	4	2	4	3	3	3	3	2	4
Participant 1	2	4	2	2	5	1	4	4	4	4	4	2	5

Road Type	Road Event 29 4 Passat - Motorway												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	1	5	1	1	5	1	5	5	5	4	5	1	4
Participant 24	2	5	1	2	5	1	5	5	5	5	5	2	4
Participant 23	2	5	2	2	4	2	5	4	4	4	4	2	5
Participant 22	2	5	1	1	5	1	4	4	4	4	4	1	5
Participant 21	2	5	1	1	3	2	4	4	4	4	4	2	3
Participant 20	1	5	1	2	5	1	5	5	5	4	5	1	4
Participant 19	1	5	1	1	5	1	5	5	5	5	5	1	1
Participant 18	2	4	4	3	5	1	4	3	4	4	4	2	5
Participant 17	1	5	2	1	5	1	4	5	4	4	5	1	5
Participant 13	1	5	1	2	5	1	5	5	2	5	5	4	5
Participant 12	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 14	2	5	2	1	4	2	2	4	5	4	5	2	4
Participant 13	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 12	1	5	1	4	5	2	4	5	5	5	5	1	5
Participant 11	1	5	1	2	4	1	5	5	5	5	5	1	5
Participant 10	5	5	1	4	5	2	4	5	5	5	5	1	5
Participant 9	1	5	1	1	5	1	2	5	5	5	5	1	4
Participant 8	1	5	1	2	5	1	4	5	5	4	5	2	5
Participant 7	1	5	1	1	5	1	5	5	5	5	5	1	5
Participant 6	1	5	1	2	5	1	5	5	5	4	4	1	4
Participant 5	2	4	4	4	5	1	4	2	4	4	4	2	5
Participant 4	1	5	1	2	5	1	5	5	5	5	5	1	5
Participant 3	2	4	2	2	4	2	2	2	4	4	4	2	4
Participant 2	1	4	2	2	5	1	5	5	4	5	4	2	5
Participant 1	2	4	2	3	4	1	4	4	2	4	4	4	4

Road Type	Road Event 30 5 Polo - Rumble Strips												
	acceptable	calm	comfortable	pleasant	in-control	safe	powerful	alarming	bumpy	sharp	smooth	regular	grippy
Participant 25	5	1	5	5	1	5	1	1	1	2	1	5	2
Participant 24	4	1	5	4	2	4	2	1	2	2	2	4	2
Participant 23	5	1	5	5	2	5	2	1	1	1	1	5	1
Participant 22	4	1	5	4	1	3	2	1	2	2	2	4	1
Participant 21	4	1	4	5	2	4	1	1	2	1	1	2	3
Participant 20	4	2	4	4	3	3	2	2	2	2	2	4	3
Participant 19	3	2	4	3	3	3	3	2	3	3	2	3	3
Participant 18	5	2	5	4	3	2	1	1	1	1	1	4	3
Participant 17	5	1	5	5	1	5	1	1	1	1	1	5	1
Participant 13	4	2	3	4	3	2	2	2	2	2	1	4	3
Participant 12	5	1	4	3	2	4	1	2	1	1	2	4	2
Participant 14	4	1	5	5	1	4	1	1	1	1	1	5	1
Participant 13	3	2	4	3	3	4	3	2	3	1	2	3	3
Participant 12	4	1	4	4	4	2	2	1	1	1	2	2	2
Participant 11	3	2	2	2	4	2	2	1	1	2	2	2	3
Participant 10	5	1	4	4	4	3	1	1	1	1	1	5	3
Participant 9	4	1	5	5	2	4	1	1	2	2	2	2	4
Participant 8	4	2	4	3	4	3	3	1	2	4	2	4	2
Participant 7	4	1	4	5	2	4	1	1	1	1	2	5	2
Participant 6	4	2	4	5	3	4	3	2	3	2	2	4	2
Participant 5	5	1	5	5	5	1	1	1	1	1	1	5	4
Participant 4	4	2	4	4	3	3	2	3	2	2	2	4	4
Participant 3	4	1	5	5	1	4	1	1	1	1	1	5	1
Participant 2	4	2	3	4	4	2	2	2	1	1	2	2	4
Participant 1	5	1	5	5	2	5	1	1	1	1	1	5	2