



# Haptics of in-car radio buttons and its relationship with engineering parameters



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## ABSTRACT

The interaction with in-car interfaces is becoming complex and multidimensional due to the addition of more and more technologies and functionalities, which can have a negative impact on driving safety. The hand exploratory behavior of in-car interfaces has been studied aiming to minimize the mental overload of the driver when looking for radio functions. Also, the subjective and emotional values associated with the interface have been considered. However, the identification and translation of these needs into design specifications is problematic. The objective of this paper is to contribute to a better understanding of these issues by studying the relationships between users' preferences and engineering parameters of in-car radio buttons and, on the other hand, the identification of the more important engineering parameters for a better definition of the in-car interface requirements. The research was done based on an empirical study and the analysis combined exploratory statistics of preference ratings and qualitative content analysis, with partial least squares regressions and artificial neural networks to link the preferences with the buttons' engineering parameters.

**Relevance to industry:** This paper proposes a set of haptic engineering parameters for in-car interface buttons in order to help the manufacturers and their clients to better define interface requirements related to subjective needs of the user, and so, with a positive impact on product development costs and delays. The developed methodology can be also used in other products.

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## 1. Introduction

The interaction between the car driver and radio interfaces is becoming complex, multidimensional and problematic because more technologies have been added to these devices (Wellings et al., 2008, ). The resulting overload of tasks causes undesirable effects on car driving. For example, the use of mobile devices when not well integrated with other car infotainment systems can distract the user and reduce driving performance (Diewald et al., 2011; Zhao et al., 2013). In particular, the driver should be concentrated on the road while at the same time exploring an interface with his or her hands in order to find specific buttons, however, given the increased functions that have been added the

user will experience increased difficulties to find the right button without looking at it. So, the tactile exploration of these interfaces should be well designed in order to help drivers to easily find the radio functions.

The way humans explore object surfaces to identify them and their topographic characteristics is known as active touch or haptics (Loomis and Lederman, 1986; Sekuler and Blake, 1994). The role of haptics in interface design is not limited to the ergonomic issues, such as designing controls and panels to avoid mistakes, accidents and reduce the mental stress of the driver; it is also related to the subjective, emotional and affective values associated with the manufacturer's image (Schütte and Eklund, 2005; Schütte et al., 2004). For example, the perception of a solid, steady and precise control is associated with an image of a high quality car. Thus, new product design approaches are essential (Chen et al., 2009; Jiao et al., 2006; Schütte and Eklund, 2005) that, supplementing the conventional one, can identify these subjective needs, translate them into design specifications and integrate them in the product

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### Abbreviations

ANN	Artificial Neural Network
EP	Exploratory Procedure
MSE	Mean Square Error
MSEP	Mean Square Prediction Error
OP	Object Property
PLSR	Partial Least Squares Regression
VIP	Variable Importance in Projection

development process at engineering, marketing and design departments (Wellings et al., 2008, ). This affective design or engineering approach brings new challenges to manufacturers because the current product development paradigm is oriented to product functional and ergonomic performance, and low cost requirements (Schütte and Eklund, 2005; Wellings et al., 2008, 2010).

New research approaches, known as generative and evaluative research type, have been developed in order to solve this product development problem (Wellings et al., 2010). The first one studies the consumer behavior, through observation and qualitative interviews while the second measures the consumer perceptive response to new products and their physical properties, and then develops relational models between these two types of data. In this context, some modeling frameworks have been proposed with the objective of building up perception models which connect product physical properties with user apprehended hedonic quality experienced during product interaction (Wellings et al., 2008, 2010), such as the well-established Quality Function Deployment (QFD), Kano's model (KM) and Kansei Engineering (KE) frameworks.

The QFD methodology systematizes and guides the product development process, by identifying the consumer needs and finding their relation to the design attributes and engineering parameters, using the "house of quality" matrices (Garibay et al., 2010; Matzler and Hinterhuber, 1998; Wellings et al., 2008). However, this is a one dimensional and proportional type approach and the increment of product performance in each one of its attributes can have different impact levels on the consumer expectations. So, the Kano model (Chen and Lee, 2009; Shahin and Zairi, 2009) has been presented in order to analyze and categorize the product attributes according to the impact they have on consumer satisfaction, by adding a second dimension on the analysis, the subjective and emotional one. On the other hand Kansei (Wellings et al., 2008) engineering studies how the objective, physical or formal product properties are related to the product affective properties experienced by users with their five senses. These formal properties can be found in the literature with different designations (Bahn et al., 2009; Chang, 2008; Chen and Chang, 2009; Chen et al., 2009; Choi and Jun 2007; Demirtas et al., 2009; Han et al., 2004; Hsiao and Chen, 2006; Ishihara et al., 1995; Jiao et al., 2006; Lai et al., 2005; Schütte and Eklund, 2005), as well the product affective properties (Chen and Chang, 2009; Demirtas et al., 2009; Ishihara et al., 1995; Lai et al., 2005). Kansei engineering applications can be found in research works dedicated to instrument panels, switches and cars (Bahn et al., 2009; Chang et al., 2006; Hsiao and Chen, 2006; Schütte and Eklund, 2005; You et al., 2006).

Other product development research frameworks have been proposed but they all depart represent improvements (Bahn et al., 2009; Chang, 2008; Chen and Lee, 2009; Evans and Burns, 2007; Han et al., 2001, 2004; Khalid and Helander, 2004; Xu et al., 2009) and integration (Chen and Chuang, 2008; Delice and Gungor, 2009; Matzler and Hinterhuber, 1998) of the above

presented frameworks. Moreover, these frameworks have presented approaches to create conceptual models of product perception based on different hierarchy of property layers, being the subjective and perceived ones located at the top level and the objective and formal ones at the bottom one. The intermediate layers are developed by decomposing the top layer until it reaches the bottom of the hierarchy. However, despite the attempts to clearly define this model, there is no consensus as regards to the conceptual structure that should be adopted as can be seen by the diversity of definitions and terms found in the literature (Gaspar et al., 2014).

So, the objective of this paper is to contribute to the development of this new paradigm with a better understanding of the relationship between user preferences and in-car interface engineering parameters, as well the identification of the most important engineering parameters for a better definition of the client interface requirements.

#### 1.1. Haptic system

The haptic system receives sensorial information, from two sensory subsystems: cutaneous and kinesthetic (Klatzky and Lederman, 1988; Lederman and Klatzky, 1987, 1993). The first senses pressure, vibration and temperature with receptors located in the skin while the second senses the position and movement of the body and its parts with receptors located in the muscles, tendons and joints. These sense data are then processed with the help of motor subsystems related to hand movement patterns or exploratory procedures (EPs) to extract object properties (OPs) (Fig. 1), which can be classified as substance (object texture, hardness, temperature and weight), structural (object weight, volume, global shape and exact shape) and functional (object's part motion and specific function) properties (Klatzky and Lederman, 1988; Lederman and Klatzky, 1987, 1990, 2004).

Some of these OPs, for example, the global shape property (d) or the envelope information of the object shape (e.g. cylindrical volume) are extracted by grabbing the object in a steady position, while the exact shape property (b) or the precise information about the shape space details (e.g. the object borders) are extracted with the finger sliding along the object surface. There are two more OP-EP relations (not in Fig. 1) that are related to the specific functions and the part motion properties. The specific function property (e.g. button cylindrical form indicates that is used to regulate sound volume) is the extracted perception of the object function from the tactile exploration of its form while the part motion property (e.g. the regulation of the sound volume button is soft) is extracted when operating the object to accomplish its function.

The object representations collected during this explorative phase are then compared with previously established categories of object representations (Klatzky and Lederman, 1988; Lederman and Klatzky, 1990), which is performed at least in three levels of increasing abstraction: the subordinate (e.g. sound volume button), basic (e.g. button) and superordinate (e.g. radio) (Lederman and Klatzky, 2004). The object properties of shape, size and texture are mostly categorized at the basic level while the thermal ones are usually categorized at the subordinate one. The remaining properties are represented in basic or subordinate levels. Section 1.3 will shed more light into this discussion.

#### 1.2. Haptic correlations with physical parameters

Some research studies have been made on in-car interface haptics, with the objective of relating switch physical properties (e.g. design parameters) with user perceptive and cognitive response. Schütte and Eklund (2005) presented a relational model

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