



A usability evaluation toolkit for In-Vehicle Information Systems (IVISs)

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ABSTRACT

Usability must be defined specifically for the context of use of the particular system under investigation. This specific context of use should also be used to guide the definition of specific usability criteria and the selection of appropriate evaluation methods. There are four principles which can guide the selection of evaluation methods, relating to the information required in the evaluation, the stage at which to apply methods, the resources required and the people involved in the evaluation. This paper presents a framework for the evaluation of usability in the context of In-Vehicle Information Systems (IVISs). This framework guides designers through defining usability criteria for an evaluation, selecting appropriate evaluation methods and applying those methods. These stages form an iterative process of design–evaluation–redesign with the overall aim of improving the usability of IVISs and enhancing the driving experience, without compromising the safety of the driver.

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1. An overview of usability evaluation

One of the most popular definitions of usability was provided by the International Organisation for Standardisation (1998):

[The] extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use. (1998, p. 2)

There have been many more useful definitions (in particular see Bevan, 2001; Nielsen, 1993; Norman, 1983; Shackel, 1986; Shneiderman, 1992); however, evidence has shown that there is unlikely ever to be a single universally accepted definition of usability (Harvey et al., *in press-a*). This is because consideration of the context of use is essential in defining usability criteria and this will be different for each system under investigation. One of the main purposes of defining criteria for usability is so that it can be evaluated. Usability evaluation is used to assess the extent to which a system's human–machine interface (HMI) complies with the various usability criteria which are applicable in its specific context of use. The results of a usability evaluation can be used to indicate the likely success of a product with its intended market, to compare two or more similar products, to provide feedback to inform design, and even to estimate possible training requirements associated with the product (Butler, 1996; Rennie, 1981).

2. Preparing for a usability evaluation

The main aim of this work is to develop a usability evaluation framework for In-Vehicle Information Systems (IVISs). IVISs are typically menu-based systems which enable most secondary vehicle functions to be integrated into one system and accessed via a single screen-based interface. Secondary functions relate to the control of communication, comfort, infotainment and navigation; primary functions on the other hand are those involved in maintaining safe control of the vehicle, i.e. driving (Lansdown, 2000). Before developing the IVIS usability evaluation framework, a number of features relating to this specific system had to be defined. These related to the interactions which occur between the tasks, users and system and the context of use of IVISs. It was also essential to define a comprehensive list of criteria for the usability of IVISs, in order to provide some targets for the evaluation. Based on the authors' experience of developing this evaluation framework, it is recommended that prior to conducting any usability evaluation, evaluators follow three principles to ensure that important preliminary information is carefully defined: these are presented in Table 1. The application of each principle to IVISs is described in the following sections.

2.1. Defining the task–user–system interaction for IVISs

The usability of an IVIS is affected by the HMI, which determines how well a driver can input information, receive and understand outputs and monitor the state of the systems (Cellario, 2001; Daimon

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Table 1
Three general principles for preparing an evaluation.

Define the task–user–system interaction	These three factors determine the usability of a system and the way in which they will be represented in the evaluation needs to be determined. Unlike the task and the system, the designer has no control over the user of the system; however the needs of the user and their conceptual model of the interaction must be considered in design (Landauer, 1997; Norman, 2002; Preece et al., 2002; Walker et al., 2001).
Define the context of use	The usability of a system is dependent on the context within which it is used. This is because certain attributes of usability will be more or less important depending on the circumstances in which a system is used (Chamorro-Koc et al., 2008; Greenberg and Buxton, 2008). All factors which influence this context of use need to be identified.
Define usability criteria	Before a system can be evaluated, evaluators need to know which aspects of the interaction are relevant to usability. Usability criteria, which define a target level of usability, need to be developed (Harvey et al., in press-a).

and Kawashima, 1996; Stanton and Salmon, 2009). The driver can input information to the IVIS via two modes: physical, which for most IVISs involves movements such as pushing buttons and turning dials; and verbal, which can involve the user speaking commands which the system interprets and responds to. IVIS outputs are generally made through three modes: visual, auditory and physical, of which the first is most widely used. As well as sending and receiving information to and from the IVIS, the driver must also process this information via the cognitive mode. The success of these interactions will be influenced by the structure of tasks and the design of the system interface, which the designer is able to control. The interaction will also be affected by the characteristics of users. It is not possible for designers to control these characteristics; however, to ensure a high level of usability these characteristics must be accounted for in design. This is a difficult skill as there is a tendency for people, including designers, to believe that they are aware of the determinants of their own behaviour and satisfaction and that their own needs and perceptions of a particular system are equally applicable to everyone else. This is described as the 'egocentric intuition fallacy' (Landauer, 1997). Norman (2002) recommended that in order to avoid making these mistakes, designers must be able to instil in the user the appropriate conceptual model of an HMI through good design. Evaluation with users is probably the most effective way to ensure this user-centred design because their performance and attitudes will highlight the variability which designers find almost impossible to predict.

2.2. Defining the context of use for IVISs

A thematic analysis was conducted in the context of IVISs to identify six main factors which influence usability (Harvey et al., in press-a):

- Dual task environment
- Range of users
- Environmental conditions
- Training provision
- Frequency of use
- Uptake

The context of use within which the usability of an IVIS must be defined is perhaps more important than many other products

because it is closely linked to additional, safety–critical interactions and the impact on these must be carefully considered. Fastrez and Haué (2008) suggested that the high diversity of the driving context also increases the complexity of designing for usability, compared with other products and systems. With respect to this context of use, the IVIS should be usable by the driver within the dual task driving environment. This means that the secondary tasks performed via a usable IVIS should not interfere with the concurrent driving task. An IVIS should be usable by the entire population of potential users, which in a driving environment, comprises of a diverse range of user characteristics. The wider driving environment, including road, weather and in-vehicle conditions, must also be considered as an influence in this context. The design of an IVIS should account for limits in training provision and for varying frequencies of use. It should also ensure that there is successful uptake of the system by users.

2.3. Defining usability criteria for IVISs

Thirteen criteria specific to IVISs were defined in relation to the six context of use factors described in the previous section (Harvey et al., in press-a). Criteria from general definitions of usability, such as efficiency, effectiveness and satisfaction (Bevan, 2001; International Organization for Standardization, 1998; Nielsen, 1993; Norman, 1983; Shackel, 1986; Shneiderman, 1992), were adapted to suit the specific context of use for IVISs. Selection was also guided by the relevance of criteria to driver needs, which were described by Harvey et al. (in press-b) as safety, efficiency and enjoyment. The six context of use factors and thirteen IVIS usability criteria are presented in Fig. 1. These criteria collectively define usability for IVISs and each is measurable, either objectively or subjectively. This means that the usability of these systems can be comprehensively evaluated, i.e. all attributes of usability which are significant in the context of human interaction with IVISs will be covered in an evaluation guided by these criteria.

3. Selecting usability evaluation methods

The success of usability evaluation depends on the appropriateness of the selection of evaluation methods (Annett, 2002; Kantowitz, 1992). The selection of usability evaluation methods will be a matter of judgement on the part of the evaluator (Annett, 2002) and it is therefore important that he/she has as much information as possible to inform this choice and to ensure that the evaluation is not weakened by the use of inappropriate methods (Hornbæk, 2006; Kwahk and Han, 2002). Four principles to guide the method selection process were defined following a review of the literature on usability evaluation, in which many authors advised that consideration of the type of information required, the stage of evaluation, the resources required and people involved is essential in the selection of appropriate methods (see for example, Butters and Dixon, 1998; Johnson et al., 1989; Kwahk and Han, 2002; Stanton and Young, 1999b). These four principles, presented and defined in Table 2, are closely interrelated and trade-offs will need to be carefully considered in order to identify appropriate methods in accordance with this guidance.

3.1. Information requirements for IVIS usability evaluations

The information required from an evaluation of IVIS usability was defined in the thirteen usability criteria presented in Section 2. Methods were assessed according to their abilities to produce this information. Methods were distinguished based on the type of data they deal with; specifically, whether this data is objective or subjective. According to the usability criteria defined for IVISs,

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