How to Involve Psychophysiology in the Field of Transportation: Recent Contributions to an Applied Psychophysics Problem

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ABSTRACT

Especially in the field of transportation many facets of human factors should be considered. Many of them can profit from the inclusion of psychophysiological methods. Thinking about well-designed and high-quality products that have the possibility to inspire customers, leads to the problem that subjective sound impression cannot easily be described by technical parameters. To connect customer requirements and technical specifications, subjective assessments of experts and/or customers are widely used. But subjective assessments are mostly not enough to uncover small quality differences between sounds. Therefore, a multidimensional approach that combines subjective assessments, objective physical parameters of the sounds and psychophysiological measures should be used for investigations. Results of a first investigation with in-vehicle sounds show that a multidimensional approach can support product development and can be seen as possibility to involve human factors in the highly technical environment of transportation. This method can be also usable in other areas of product development in the field of transportation. So, further research should be considered to investigate the use of a multidimensional approach in these areas too.

Keywords: Human Factors, Psychophysiology, Multidimensional Approach, Sound Quality

INTRODUCTION

In the field or transportation various possibilities exist to consider human factors. For example, during the product development process the involvement of human factors will offer engineers possibilities to define appropriate and convenient system requirements to enable a safe and easily understandable system operation. Furthermore, involving human factors can help to understand customer's product acceptance and quality demands and therefore improve product quality. Many of these research fields can profit from the inclusion of psychophysiological methods.

Psychophysiological methods

Traditionally assessments of behavior, mental workload, stress and emotions are based on self-reporting methods such as questionnaires, interviews, narrative techniques, contextual inquiries or sensor based evaluations (Isbister, Höök, Sharp and Laaksolahti, 2006). These methods are able to give an insight into emotions and preferences but the data collection process interrupts the ongoing process of system interaction. Also, describing emotions in

concrete words is sometimes very difficult for users. It is well known that human behavior, cognitive and emotional phenomena are accompanied by physiological processes of different psychophysiological systems. Thus, psychophysiological methods can be used to make activation/arousal parameters and emotional tones visible by measuring parameters of the autonomic nervous system. Beside their relatively easy measurement with non-invasive techniques via portable recorders (laboratory and field studies), one big advantage of this approach is that physiological processes are actively non-controllable under normal conditions (Boucsein, 2006; Boucsein and Backs, 2009).

It was shown that the use of one single physiological measure is not enough to reflect the different psychophysiological processes that accompany activation, emotion, and attention (Boucsein, 1989; Boucsein and Backs, 2000). So, it is recommended to combine different measures like measures of cardiovascular activity (ECG), electrodermal activity (EDA), facial muscle activity measured via electromyography (EMG), and respiration. EDA is a well-researched and valid method to detect arousal and was used successfully to measure emotions during system interaction (Mandryk, Inkpen and Calvert, 2006; Ward and Marsden, 2003). Measures of the cardiovascular system provide several possibilities to measure valence and arousal e.g. heart rate (HR) is positively correlated with arousal and heart rate variability (HRV) can be used to assess positive or negative valence of experiences (Anttonen and Surakka, 2005).

Safe and easily understandable system operation

The major goal of product development in the field of transportation is to ensure a safe and easily understandable system operation. Pilots, drivers, train conductors, and captains of ships must process a lot of information when operating an airplane, vehicle, train or ship. Therefore, measuring the performance of users with the system is an important concern in this research field. Wickens and Hollands (1999) suggest different measures of performance and behavior: Measures of speed or time, measures of accuracy or error, measures of workload or capacity demands, and measures of preference. The system operator always has to have available the necessary resources to respond to unexpected events, so mental workload can be seen as important safety-related factor (Lumsden, 2011). Beside the well-known secondary-task technique and subjective assessments, psychophysiological measures (HR, HRV, EDA, facial EMG, pupil diameter, eye movements, EEG) are successfully used to show the autonomic or central nervous activity while operating a system (Boucsein, 2006; Boucsein and Backs, 2009; Wickens and Hollands, 1999).

Product experience

If a safe and easily understandable system operation is ensured, and the new product shall be launched in the market, another problem can become more prominent: Nowadays, products become more and more similar from a customers' point of view. Therefore, it is increasingly important to make a product unique. Current developments show that ensuring excellent technological product quality is not enough to achieve market success. Thus, many organizations are looking for new ways to achieve a competitive advantage (Müller, 1990; Woodruff, 1997). One way to reach this important goal of product development is raising customer's emotions and creating products that are able to fascinate (Lee, Amir and Ariely, 2009; Pawle and Cooper, 2006). Thinking about products that are able to fascinate customers, results in considerations that bring "soft" factors like how much a customer likes a brand in the foreground. Thereby, subjective customer assessments and emotional aspects can become important decision criteria to choose between products of different brands (Havlena and Holbrook, 1986). So, to be successful a product has to become more and more a sensual experience to be perceived as something special and unique (Hirschman and Holbrook, 1982; Lindstrom, 2005; Schifferstein and Spence, 2008).

MULTIDIMENSIONAL APPROACH

Impressions that may activate in a customer while using a product, sitting in a vehicle, aircraft or train cabin, or operating with a system can be described as multidimensional. Obviously, the assessment of these impressions also has to be multidimensional. Thinking about well designed, pleasant, comfortable and high-quality products that have the possibility to inspire customers, leads to the problem that subjective impressions cannot be easily described by

technical parameters. To connect customer requirements and technical specifications, subjective assessments of experts and/or customers are widely used. But subjective assessments are mostly not enough to uncover small quality differences. Using a multidimensional approach can help to cope with this applied psychophysics problem. So, a multidimensional approach has to combine subjective assessments, objective physical parameters, and psychophysiological measures (activation and emotional reactions) (Wagner, 2013).

Example: Sound quality of turn indicator sounds

The turn indicator is an operational in-vehicle sound with signaling character (c.f. Cerrato, 2009; Mühlstedt, Unger and Spanner-Ulmer, 2007; Zeller, 2009) that gives the driver an important feedback of correct function performance. Due to hearing the turn indicator sound very often during normal drives, a sound that is not created well can become aversive and maybe also distracting to the driver. Former research has shown that the turn indicator sound is one of the vehicle sounds that are important for perceived customer's vehicle quality (Beitz, Wagner and Enigk, 2010).

In a laboratory experiment (see Wagner, 2013, 2014; Wagner and Kallus, 2013 for more details) 15 different turn indicator were assessed by 48 participants (24 men/24 women; age: M = 36.2, SD = 11.56). A multidimensional approach (subjective assessments, psychophysiological measures, and physical sound characteristics) was used to investigate, how a turn indicator must be designed to be perceived as high-quality and pleasant. The combination of these different parameters was chosen to reflect the multidimensional impression that a product sound may activate in a customer. The use of psychophysiological measures shall help to point out the activation and the emotional reactions of customers while hearing the different sounds as well as to assess small quality differences between them. Bringing physical sound parameters into the approach help to derive guidance values. These guidance values enable a fast implementation of the results into the assessed product and its sounds which is really important to develop a product successfully.

The results show that although significant differences in the subjective assessments of the different sounds do exist, they are relatively small. Only the inclusion of the psychophysiological responses (electrodermal and cardiovascular activity) of the participants on the 15 different sounds helps to show that one sound group (least assessed quality group) should not be implemented into the vehicle because of the potentially triggering of arousal in the direction of negative emotions. Also, sounds of the middle rated group should only be implemented if the wish exists to have a turn indicator sound which remains in the background. The psychophysiological responses of the participants strongly support the recommendation to implement turn indicator sounds of the best assessed quality group because they are not only able to reach positive emotions of the driver but also, at the same time prevent mental workload.

For the physical sound characteristics the results show that the perception of high-quality of turn indicator sounds can be characterized by lower values in the volume related parameters A-weighted sound pressure level [dB(A)] and specific loudness, as well as in combination with specific loudness the parameter sharpness. Interestingly, the analyses show a better prediction of perceived turn indicator sound quality by specific loudness than by A-weighted sound pressure level [dB(A)], which is normally used more often for analyses in the automotive context. In addition, the subjective assessments result in the recommendation that high-quality turn indicator sounds have to be perceived as rather gentle, soft and reserved as well as not too rough and sharp. This result is supported by the psychophysiological reactions of the participants: The level of relaxation decreases if the sound perception is not reserved, gentle and soft; too sharp and rough sounds are stronger emotional arousing and more attention-demanding; rich, dark and low pitched turn indicator sounds are most pleasant, bind least attention and result in lower arousal/fewer distraction than other turn indicator sounds.

CONCLUSIONS

Results of a first investigation with in-vehicle sounds show that a multidimensional approach can support product development and can be seen as possibility to involve human factors in the highly technical environment of transportation. This method can be also usable in other areas of product development in the field of transportation like in the assessment of (driver) distraction, the usability of different displays, switches and controls, assessments of their arrangement in the cockpit, perceptual assessments of different aspects e.g. design, haptics, tactile sensation,

feedback of driving behavior, etc. So, further research should be considered to investigate the use of a multidimensional approach in these areas too.

There are several reasons for using a multidimensional approach: The inclusion of psychophysiological measures helps the product developer to cope with the problem that subjective assessments are mostly not enough to uncover small quality differences. Moreover, the combination with physical parameters helps to derive guidance values that enable a fast implementation of study results into further product development. This can be seen as important step to develop a product successfully within timelines that are given by market cycles. Another advantage of the multidimensional approach is that beside mental workload, activation/arousal and emotional aspects are made visible. Especially, emotional aspects of products can have a strong influence on customers' decision processes. Certainly, the presented multidimensional approach can also be easily combined with often used usability techniques of measuring time on task, success or accuracy.

To sum up, the results of the presented study show that the use of a multidimensional approach can be seen as important step to bring together subjective and objective aspects of products and their perception and helps to determine optimization options for further product development in the field of transportation.

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