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Design of Consumer Products: A User-Centered Approach

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1 INTRODUCTION

The design of consumer products has become a growing research field over recent years. This is largely due to the economic importance of the field, as the market of consumer products represents a substantial share of the economic output. However, compared to other fields of ergonomic research, the overall quantity of published research may still be considered to be moderate. This may be partly due to the fact that a substantial amount of work has been carried out in industry, which is largely inaccessible to the scientific community.

The research that has been published may be found in two rather separate research fields. There is the field of engineering psychology that may be considered the home of traditional ergonomic research, having its primary focus on safety and usability issues. The second field is industrial design, in which consumer psychological issues also play a major role. In particular, the concepts of pleasure and joy in product usage have featured prominently in that research strand (Norman 2004).

For the purpose of this entry, consumer products may be broadly defined as technical products that are used outside the work context, such as during domestic and recreational activities. The fact that product usage takes place in a nonwork context is important since there are a number of points in which the domestic (and recreational) domain differs from a work environment (Sauer *et al.* 2002). First, domestic users are characterized by high heterogeneity. Second, domestic users are not selected for their competence to operate consumer products. Third, no formal training is usually given to domestic users. Fourth, tasks in the domestic domain are mainly self-defined by the user. Fifth, performance of domestic users is usually not supervised and no performance feedback is received from other users. This shows that the possibilities of modifying user behavior are much more limited in the domestic domain than in work environments. Therefore, the design of the product represents the main means to influence user behavior.

Consumer products comprise a wide range of products, which includes mechanical products (e.g. knife) as well as power-driven products (e.g. washing machine, car). They may differ in their complexity for user–product interaction, with pairs of scissors (low complexity), vacuum cleaners (medium complexity), and central heating system (high complexity) representing typical examples of different complexity levels. Complexity in user–product interaction may not necessarily be congruent with technical complexity. For example, the television as a highly complex appliance in a technical sense is generally quite easy to operate for users. More complex products are of greater interest to human factors specialists because of higher cognitive demands, higher risk of errors, and greater potential for user dissatisfaction. This chapter primarily focuses on those consumer products that pose at least a moderate amount of cognitive demands on their users. Examples of these consumer products are coffee machine, video recorder, lawn mower, dishwasher, and central heating system. Cars and personal computers would also belong to that group but they are covered in separate chapters of this volume (see xxxx and xxxx). Of the many research questions and practical issues that surround the design of consumer products, this chapter concentrates on four major aspects. It presents goals and criteria of consumer product design, examines the product design process, provides examples of empirical studies in the field and, finally, outlines trends in the research field.

2 CRITERIA FOR CONSUMER PRODUCT DESIGN

When designing consumer products, it is necessary to determine primary design criteria. The following primary design criteria are generally considered to be most relevant: safety, usability, environmental-friendliness, and marketability.

The safety of consumer products is the most fundamental design criterion since it aims to minimize any risk of injury resulting from product use. The number of household accidents is considerable and, in industrialized countries, generally exceeds the number of accidents at work, which clearly demonstrates the importance of safety aspects in consumer product design. Norris and Wilson (1999) suggest four steps in designing consumer products for safe use: Identification of all possible users (including unintended users), identification of all possible hazards, setting of performance criteria and test variables, and selection of methods for safety testing. Of particular importance for product design for safe use is the consideration of unintended users, since consumer products may be accessible to groups of people for which they were not designed (e.g. children).

A consumer product also needs to fulfill usability criteria, that is, it should be easy to learn, efficient to use, easy to remember, subjectively pleasing, and characterized by few user errors (Nielsen 1993). The concept of usability has to be assessed in relation to a certain group of target users (e.g. experts, novices) and in the context of carrying out certain tasks. For example, an expert user of a camera wishing to take a picture of a landscape in twilight may have different needs compared to a novice user wishing to take a family snapshot. As a result of the importance of the concept of usability for product design, usability has also been defined in ISO norms (ISO 9241).

More recently, the criterion of environmental-friendliness has been considered to be a further aspect of good product design. The concept of environmental-friendliness is not limited to choosing recyclable materials or developing more energy-efficient motors. Rather than improving materials and technical efficiency measures, it considers efficient user–product interaction as a major determining factor for reducing the environmental impact of a consumer product. Research evidence has clearly demonstrated the importance of the product utilization phase for the total environmental impact of a product, compared to preceding and subsequent phases of the product's life cycle (e.g. manufacturing, recycling) (Wenzel *et al.* 1997). This is largely due to the considerable resource consumption (e.g. energy, water) during product utilization.

Product designers also have to consider the issue of marketability. While this criterion has not played a central role in traditional engineering psychology, it was addressed by research in industrial design and consumer psychology. This division of the field may be unfortunate since good ergonomic design may have little impact if it does not meet customer expectations. The goal of meeting customer expectations is of particular importance in the domestic domain since the product user is also the product purchaser, which indicates a different decision-making process in the domestic domain compared to a work environment.

While it is desirable to meet all the design criteria outlined, in practice this may be difficult to achieve so that trade-offs need to be made. For example, it may be necessary to make a trade-off between the usability criteria learnability and efficiency of use since they reflect the different needs of novice and expert users (Nielsen 1993). Similarly, there may be a conflict between demands for environmental friendliness and marketability, which may be resolved by designing a moderately environmentally friendly consumer product that is highly successful in the marketplace rather than a highly environmentally friendly consumer product that does not meet market expectations. This reiterates the argument for a stronger consideration of consumer psychological issues in ergonomic design approaches.

3 PRODUCT DESIGN PROCESS FOR CONSUMER PRODUCTS

In order to meet the design criteria outlined above, there are a number of ergonomic methods available, which support the designer in defining product specifications, as well as evaluating prototypes (Jordan 1998; Norris and Wilson 1999; Stanton and Young 1999). When selecting a particular method, a number of factors have to be considered, such as time pressure, expertise of product analyst, measures of interest (e.g. error rate, user movements), and phase of product design process (e.g. early, middle, late). Of particular relevance are the different phases of the product design process.

3.1 Product Design Models

The research literature provides a number of phase models for describing the product design process. These models help distinguish between different phases of the design process so that it can be determined in which phase a given ergonomic method can be employed most effectively. As a prominent example, the model of Stanton and Young (Stanton and Young 1999) is described here. It distinguishes between four phases: (a) *Concept*: At this stage product specifications have been formulated but no blueprints have been defined yet. (b) *Design*: This covers the period between formalized product specifications and the development of the first prototype. (c) *Prototype*: A prototype has been developed, which may be available in two forms, either as an analytical prototype or as a structural prototype. The analytical prototype is a representation of the product in a virtual form, for example, by means of a CAD system. The structural prototype refers to the development of a hard-built prototype, which may not be entirely complete (e.g. it may lack some functions). (d) *Operational product*: This is a fully operational device comprising all product functions.

3.2 Ergonomic Methods for Product Design

Since there are a considerable number of methods available for the design of consumer products, it allows the designer to select the most suitable one by taking into consideration psychometric properties (e.g. reliability, validity), as well as contingency factors (e.g. time requirements, budgetary constraints). There are several sources that provide an overview of the utility of different methods (Jordan 1998; Nielsen 1993; Stanton and Young 1999). Generally, the evaluation of the effectiveness of these methods is based on experience rather than rigorous empirical testing. An exception to this is the work of Stanton and Young (Stanton and Young 1999), who have carried out an empirical comparison of 12 methods during the design of two car stereos. The results of the comparative study are summarized in Table 1.

The table provides analysts with information about the conditions under which a method is best applied (aspects of prototype, design stage, time available) and also gives some indications of the relative utility of each method (reliability, validity, usability). The methods differ with regard to the aspect of a prototype that is being examined. One may distinguish between *functional analysis* (examines the range of functions available), *scenario analysis* (performance of particular sequences of activities), and *structural analysis* (nondestructive testing from a user-centered perspective). *Time requirement* refers to the time the analyst should have available for analysis. Methods also differ in the kind of *output* they produce (e.g. errors, performance times, product usability, and product design). Furthermore, methods differ with regard to their appropriateness for use in different *design stages*. The design stage indicates the earliest possible stage when the method should be applied. Finally, the methods were evaluated against a number of criteria (reliability/validity, resource requirements, and method usability) by using a three-point rating system (the more stars, the more positive the rating). The comparative evaluation provides first indications of the relative strengths and weaknesses of ergonomic methods that are based on empirical evidence rather than expert judgments alone.Measures to influence user–product interaction

There are a number of design measures available that can be used by the designer to ensure that primary design criteria are fulfilled. In this section, we give selected examples of measures that were employed in empirical research with a view to modify user–product interaction. Empirical research in ergonomic design of consumer products is characterized by a rather incoherent picture. This is because the research questions addressed differed widely across studies. Because of the diverse and broad nature of the research, the present chapter will refer to selected topics that have been of importance in consumer product design, such as automation, menu-driven interfaces, product information, and system feedback.

3.2.1 Automation

While automation has long been present in many work environments, it is also advancing rapidly in the domestic domain. The most prominent examples are central heating systems, washing machines, and dishwashers. The availability of powerful processors at low prices allows the implementation of more automatic devices that take over functions formerly carried out by the human. This may be intended by the designer if the user does not perform a function as expected, which may be due to (a) performance limitations or (b) habits and lack of motivation. The automation of power control in vacuum cleaners is one example that demonstrated the successful implementation of automatic functions for the purpose of increasing product usability (Sauer *et al.* 2004).

3.2.3 Menu-driven interfaces

An increasing number of modern appliances make use of menu-driven interfaces, as they are found in telephones, washing machines, and video recorders. These appliances are characterized by an increasingly complex human-machine dialogue because of an augmenting number of system functions integrated in the appliance that need to be activated by some form of human–machine dialogue. Problems in user–product interaction with menu-driven interfaces are typically caused by inadequate system feedback, low error tolerance and non-self-evident system features. Work by Thomas and van Leeuwen (1999) provides an example of how the usability of a telephone was improved, with the design of the human–machine dialogue being a major focus of the work.

3.2.3 Product information

This refers to instruction manuals or labels directly attached to the product (so-called on-product information), which convey critical information to the user. In practice, product information often has the important but not really desirable function of compensating for design deficiencies. For example, rather than building an interface that permits an intuitive and largely self-explanatory system operation, the user has to consult the instruction manual to find out how to operate the device. Another example is that a warning label is used to point out a hazard rather than removing the hazard itself. Overall, the use of product information can be effective if it is well designed, that is, it meets the following criteria (Wogalter 1999): The product information needs to be noticed and understood. Furthermore, it needs to correspond to the individual's beliefs and attitudes and, lastly, it must motivate individuals to comply with its message. There is empirical research that has demonstrated the effectiveness of product information in the context of warnings, (Wogalter *et al.* 1987) as well as environmentally friendly product use (Sauer *et al.* 2003).

3.2.4 System feedback

In contrast to the static features of product information, system feedback is provided in a dynamic form, that is, changes in system state are fed back to the user (e.g. the water temperature in a central heating system). The system information can be conveyed in a direct form such as

TABLE 1
Selection Guideline and Evaluation of Analysis Methods for Designing Consumer Products (Adapted from Stanton and Young 1999)

Method	Description	Aspect of Prototype	Time Requirement	Output Data	Design Stage[a] (1–3)			Reliability/ Validity	Resources	Usability
Heuristic analysis	Expert-based product evaluation with regard to safety, usability, and design quality	Scenario analysis	Low	Usability and design	x	x	x	*	***	**
Checklists	Evaluation of product against a list of product specifications	Functional analysis	Low	Usability and design	x	x	x	*	***	***
Observation	Observation of user during completion of task scenarios	Structural analysis	Low	Errors and times			x	**	***	**
Interviews	Direct questioning of user by employing a structured or semi-structured interview schedule	Functional analysis	Medium	Usability	x	x	x	*	**	**
Questionnaires	Evaluation of product based on a set of questions that may include open-ended questions, rating scales, etc	Functional analysis	Low	Usability			x	NA	***	***
Link analysis	Analysis of hand or eye movements between product elements with a view to reduce distances	Scenario analysis	Medium	Design		x	x	**	**	**
Layout analysis	Analysis of functional grouping of interface elements on the basis of expert knowledge	Scenario analysis	Low	Design		x	x	*	***	***
Hierarchic task analysis	Decomposition of task by producing a hierarchy of operations and plans	Scenario analysis	High	Usability	x	x	x	*	*	**
Predictive human error analysis (PHEA)	Estimation of probability and criticality of errors	Structural analysis	High	Design		x	x	**	*	**
Repertory grids	Identification of central constructs of product by means of multiple comparisons of product elements	Functional analysis	Medium	Usability and design	x	x	x	*	**	***
Keystroke level model (KLM)	Technique to predict duration of task execution	Structural analysis	Medium	Times		x	x	***	**	***
Task analysis for error identification (TAFEI)	Error prediction by modeling user–product interaction	Structural analysis	High	Errors and design		x	x	NA	*	**

NA, not available.
[a] Design stage: 1, concept; 2, design; 3, prototype; the more stars, the more positive is the rating.

increased transparency (e.g. current water levels in kettle are directly visible through a transparent kettle body) or in the form of aggregated information on a display (e.g. mean energy consumption). There is empirical work that has demonstrated that both forms of system feedback can be effective. For example, an increase in the transparency of kettles led to reduced resource consumption (Sauer and Rüttinger 2004) and the availability of product-integrated feedback in washing machines resulted in more energy-efficient product usage (McCally and Midden 2002).

These examples of empirical work have indicated the options available to designers to improve user–product interaction. In the context of conducting empirical research, it is important to model the particular situational factors of appliance usage. For example, for the design of an alarm clock it needs to be considered that users need to be able to operate the appliance when they are not fully awake yet and when in the dark. Another example is the design of a car stereo, which needs to be operated by the user while driving. This gives the operation of the appliance the status of a secondary task, whereas the driving task requires most attentional resources. Both examples demonstrate the need to create scenarios of user testing that fully model suboptimal situational circumstances, allowing problems in user–product interaction to be readily identified.

4 CONCLUSION AND OUTLOOK

In the coming years, there may be several trends that will influence the design of consumer products and need to be addressed by the discipline of ergonomics. First, there will be a stronger integration of technical systems in that several systems are operated via a single control panel (e.g. shutters, central heating, and lights are integrated into one control device). These systems may be controlled from a proximal control device (e.g. home-based computer) but may also be accessible from a long distance (e.g. via the Internet or mobile phone). The increased system complexity ensuing from these developments makes ergonomic testing even more important. Second, the level of automation of a domestic system will increase in that manual aspects of device operation become less relevant while supervisory control is gaining in importance (e.g. manually operated vacuum cleaners are replaced by robotic vacuum cleaners). This suggests that the role of cognitive ergonomics in consumer product design is strengthened.

Future design endeavors will also need to consider more strongly the need for market segmentation, which divides the user population into several subgroups (e.g. users with special needs, such as the elderly or disabled). This requires the design of product variants that meet the specific needs of these special user groups. Interestingly, the design of appliances for special user groups can also bring benefits to users without special needs. An example of this is the television remote control, which was originally developed for users with limited mobility but is now widely used by able-bodied users, too (Jordan 1998). Consumer product design for international markets also needs to consider more fully culture-specific differences between users. For example, there are culture-dependent population stereotypes for the preferred direction of movement to activate a switch (e.g. North Americans move the switch upward to turn on the light, while Europeans move it the opposite direction).

The trends and developments outlined, be it stronger system integration and increased automation or greater market segmentation and culture-specific differences, demonstrate the need for a strong user orientation in consumer product design. Against this background, the authors would expect that in the future the design of consumer products will further gain in importance within the field of human factors and ergonomics.

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