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Case Study B

Designing Technology for Work and Home Applications

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Background

Project goals

The goal of the project was to design marketable environmentally friendly technical systems and to create and apply methods and tools that support their development. This was done in close collaboration with manufacturers and a number of research teams from different disciplines, such as occupational psychology, engineering and computer science. The present chapter will be chiefly concerned with the contribution of psychology to this goal.

The contribution of psychology in the present project mainly stems from two fields: ergonomics and consumer psychology. While ergonomics focused on improving the design of the technical systems with a particular emphasis on the criterion of environmental friendliness, consumer psychology was concerned with user perceptions of the product and aimed to assess the attractiveness of different product features for users. The close collaboration of these two fields is crucial because it is insufficient if good ergonomic design merely improves the environmental friendliness of technical systems but these systems are not attractive to consumers. In that case, they would not sell in sufficiently large numbers at the expense of less environmentally friendly systems.

The technical systems examined in the course of the project were used in work contexts (e.g., floor scrubber) as well as in the domestic domain (e.g., kettle). Some of these may be considered dual-domain systems (e.g., vacuum cleaner). The systems analyzed are of low or medium complexity, which makes them distinct from highly complex systems (e.g., aircraft, nuclear power plants) that generally dominate research in industrial ergonomics. The focus on environmental friendliness (e.g., energy and water consumption) as an important design criterion gives this project a new angle since this aspect has rarely been explicitly examined in ergonomics. However, it may have played a role hitherto as a subsidiary efficiency indicator in system design (e.g., petrol consumption for cockpit design). The contribution of psychology to that end is considered to be very important since analyses have demonstrated showed that, on average, about 80 percent of the environmental impact of energy-driven consumer products occurs during product utilization phase (i.e. during user–product interaction), as opposed to preceding and subsequent phases of the product life cycle, such as production or disposal

(Wenzel, Hausschild, & Alting, 1997).

Project structure and agreement process
During the course of the project, the psychology research team worked with several manufacturing companies to improve ergonomic design and marketability of their systems. This included a manufacturer of cleaning equipment (e.g., floor scrubber, high pressure washer) and the makers of electrical body care products (e.g., hair drier) as the main collaborators.

The process of agreement for carrying out the project comprised two main steps. First, a project team was formed before a formal agreement was reached. Over a time period of several months, shared interests between the research group and the industrial collaborator were identified. This involved in some cases the completion of pilot studies to give the collaborator an indication of the kind of support that can be given by the research team. After extensive discussions of the project plan, it was subsequently specified in writing, including milestones and deliverables of each collaborator. Second, the project plan was submitted to a public funding body that employed two chief criteria for funding the work: (a) the scientific value of the proposal and (b) to what extent scientific knowledge can be transferred to industry to improve their competitive edge. The costs incurring in the research institutions were covered by the funding body while the industrial collaborator covered their own expenses. An important deliverable to be provided by the collaborator was to develop and make available various prototypes for human factors testing.

Theoretical and Practical Issues

Role of theory
While the project clearly had an applied focus, the work benefited from the use of several theories and models of the research literature. For example, action theory (Frese & Zapf, 1994) was employed for carrying out analyses of user tasks. Furthermore, models of information processing (e.g., Rogers, Lamson, & Rousseau, 2000) were used for the design of effective on-product information. To provide a third example, resource models were employed to explain changes in user behavior under varying cognitive-energetical demands (e.g., "variable state activation theory" from Hockey, 1997). The use of all these theories and models provided helpful support for the research team in guiding the project work.

Special project skills
In order to successfully complete the project with the industrial collaborators, a number of skills were found to be very helpful during project completion. (1) It was important to provide illustrative examples to demonstrate the contribution of work psychology since in engineering-driven manufacturing companies the possible contribution of psychology to the design process may not be that

evident. (2) It was also important to be able to adopt the perspective of the organization, which was driven by market- and cost-orientation. The use of scientific empirical studies had to be justified in terms of their incurring cost with regard to time and financial resources.

Action and Outcome

Project activities
The activities within the project were mainly concerned with the design and development of new products or the modification of existing products. During the course of the project, 9 different technical systems were examined (e.g., high pressure washer, central heating system). While some of the project work was carried out inside the organization of the industrial collaborators (e.g., interviews and surveys), most of the project work focused on the user and the context of technology usage (e.g., by simulating usage context in human factors laboratory of research team or by completing field studies in work setting of system operators) rather than taking place in the organizational context of the manufacturer.

When working on ergonomic system improvements, the typical methodological approach adopted comprised five steps. First, an analysis of the human–system interaction was carried out, employing methods such as observation, interviews and questionnaires (e.g., user of central heating system was interviewed). Second, the data collected permitted the identification of problems in human–system interaction that led to nonoptimal product usage with regard to environmental friendliness (e.g., behaviors were reported that resulted in excessive energy consumption). Third, based on the problems identified in human–system interaction, design modifications were developed to improve environmentally friendly system use (e.g., interface for heating system was developed that provided better user support). Fourth, these measures were empirically tested in lab and field studies to evaluate their effectiveness (e.g., interface was tested with prospective users). Fifth, based on the results of these tests, recommendations for system designers were given (e.g., to provide an efficiency index of system operation).

Results
The project identified several impediments to environmentally friendly behavior, such as habits, lack of motivation and, in some cases, insufficient knowledge. For example, habitual behavior patterns play an important role for user–technology interaction if it involves the use of simple systems that are used very frequently. This applies in particular to the domestic domain because technical systems are of lower complexity than at work.

The project also demonstrated the effectiveness of a number of

Table B1: Estimated effectiveness of measures to deal with different causes of nonoptimal user behavior (high***, medium**, low*)

	Habits	*Lack of knowledge*	*Lack of motivation*
Static on-product information	*	**	*
Dynamic feedback	**	***	*
Enhanced controls design	**	**	*
Automation	***	**	***

design modifications in dealing with these impediments by improving environmentally friendly behavior. Interestingly, the different design measures (e.g., static on-product information, dynamic feedback about system state, enhanced control design, automation of functions) had differential effects depending on the underlying cause of the problem. For example, lack of knowledge may be dealt with by on-product information or dynamic feedback whereas these measures may not be helpful if the cause was lack of motivation to show environmentally friendly behavior. Table B1 provides a summary of the overall effectiveness of design measures as a function of the underlying causes of environmentally damaging behavior.

The kind of work carried out in the project is illustrated with an example from vacuum cleaner design, in which knowledge deficits and undesirable habits have been identified as the cause of non-ecological user behavior. Technical analyses of our collaborating engineers have revealed that a motor power level of around 750 W is most efficient for performance of a vacuum cleaner, with increases in motor power above that level providing at best marginal gains in suction performance. At the same time, a manufacturer produced a vacuum cleaner with that level of power but it was unsuccessful on the market because consumers were not convinced (i.e. they had insufficient knowledge) that the 750 W model was equal to a 1500 W model with regard to suction performance. This illustrates the obvious conflict between fulfilling the criterion of environmental friendliness (i.e. energy consumption of around 750 W) and, at the same time, market demands (i.e. the higher the motor power, the more attractive the appliance). Following in-depth analyses of user behavior, a solution to this conflict was to provide the user with a powerful model as requested but which was equipped with an automated power control function. Automation was implemented in the form of an auto reset function, which meant that the power control was reset to its most efficient level (around 750 W) every time the appliance was switched off. This is the same principle as the default setting for volume control of a TV-set, which is reset to its default level every time the appliance is switched off.

The reset function allowed users to select higher power level if they wished to do so (i.e. it was a form of automation that did not constrain actions of the user) but empirical testing revealed that nearly half of the users did not override the automation (Sauer, Wiese, & Rüttinger, 2004). Overall, the results of that experiment provided clear evidence that this design modification was effective in improving environmental friendliness of the appliance while maintaining its attractiveness to consumers. It reiterates the point that automation is highly effective in dealing with knowledge deficits but also stresses the importance to provide the user with sufficient decision latitude to choose settings that may be nonoptimal in terms of operational efficiency but may meet the personal need for control and for a powerful appliance.

Finally, some methodological effects observed during the empirical work are referred to. It was found that these influenced the estimated effectiveness of design measures (e.g., Sauer & Ruettinger, 2004). Generally, in scenarios of high fidelity (e.g., a field study using a fully operational prototype) the effects of design modifications (e.g., providing on-product information) were found to be much weaker than in lower-fidelity scenarios (e.g., laboratory study with a paper mock-up) on ecological user behavior. This does not suggest that lab-based studies are not suitable but rather that a correction needs to be made in order to make an accurate assessment of the effect size in the real world.

Practical constraints

A few practical constraints were encountered during the completion of the project. First, industrial collaborators often provided several contact persons (e.g., because they were responsible for different products). While this was very helpful because an expert for each area was available, the drawback was that it slowed down the decision-making process because of the larger number of people involved. Second, the time schedules of BSc and MSc students who were also involved in the project work did not always coincide with the required time schedule of the project. This sometimes required modifications of the project plan.

Evaluation

Evaluations were carried out at several levels to determine whether the project goals have been met. (1) According to the goals of the projects, technological devices were evaluated with regard to several already existing criteria, such as usability, marketability and environmental friendliness. At a more specific level, this included aspects like error tolerance, pleasure in product operation, and energy consumption. (2) A further evaluation criterion concerned the satisfaction of the industrial collaborator with work progress and project results. This was achieved during regular project meetings. (3) An additional evaluation criterion referred to the knowledge transfer from academic institutions into industry and vice versa. For example, this concerned the question whether work activities of the research team would be continued by the industrial collaborator after the termination of the project (e.g., human factor testing).

What Would You Do Differently Next Time?

A number of lessons have been learnt from this project. (1) In the next project of this kind, we would aim to achieve a stronger centralization of responsibility on the side of the industrial collaborator. (2) Furthermore, there should be a stronger outcome orientation rather than a methodological orientation, with the latter being perhaps more typical for academic work. This should already be specified in the project planning stage in that tangible deliverables are specified (e.g., checklists, newly built prototypes, list of design recommendations). (3) There should be a stronger involvement of the industrial collaborators in evaluation research to ensure a stronger knowledge transfer from the academic institutions to industry. This may also involve running training courses in the collaborating organization. (4) A more precise definition of the researcher's role at the beginning of project may be helpful. It needs to be made clearer that the researcher is not always able to provide instant answers to all problem situations encountered by using his/her expert knowledge. The completion of empirical tests is often required to provide answers.