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User Behavior and Technology Development
Shaping Sustainable Relations Between Consumers and Technologies

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PREFACE

Adriaan Slob and Peter-Paul Verbeek

This book is the result of an interdisciplinary project that was granted by the Netherlands Ministry of Housing, Physical Planning and the Environment, and AVV, the Transport Research Centre, which is related to the Ministry of Transport, Public Works and Water Management. TNO and the University of Twente also supported the project. We are grateful for these grants. Without them, this book would not have appeared.

The project was coordinated by Novem, the Netherlands Agency for Energy and the Environment. We are grateful to the respective project managers of Novem, and especially to Jessica Dirks, for their efforts to keep the project on track.

The assistance of Steven Dorrestijn and Mario Willems, with respect to organizing sessions and the contents of this book proved to be indispensable. We owe a lot to Jean-Marie Buijs who helped us with compiling all contributions to the book. Marian Nieuwenhout took care of the lay-out of this book in a careful and skilful way. We would like to thank Jeff Berman for his kind permission to reproduce the photographs on the book cover.

The contributions to this book are the result of an intensive interaction process between researchers from a variety of disciplines, which are all somehow connected to the domain of technology and behavior. The inspiration that sparkled from the sessions provided the energy to make this book. We would like to thank all contributors for that. The meetings with our co-editors Han Brezet, Wim Hafkamp, Wim Heijs, and Cees Midden were always pleasant and fruitful. It was a pleasure to cooperate with so many people and exchange different ideas and concepts. We hope that this book
Preface

may be a first step in the direction of a school of 'technology and behavior' scientists.

Adriaan Slob, Peter-Paul Verbeek
July 2005
PART 1

CONCEPTUAL FRAMEWORKS FOR ANALYZING TECHNOLOGY AND BEHAVIOR
Chapter 1

TECHNOLOGY AND USER BEHAVIOR:
An Introduction

Adriaan Slob and Peter-Paul Verbeek

1. THE INTRIGUING INTERACTIONS BETWEEN TECHNOLOGY AND BEHAVIOR

An elderly woman who is an acquaintance of one of us has a small wooden dwelling on an allotment, much like so many in the Netherlands. Electricity is not available. With the decline in prices of Photovoltaic solar energy, it became worthwhile for her to buy a PV unit, so her sons advised her to buy a set. A set of two PV collectors and a battery for storage of the electricity — so that the electricity generated during the day could be consumed in the evening — were installed. But things appeared to be more complicated than her sons had thought. After only two years, the battery was not functioning any more as it should; it did not store as much electricity as it used to do. The lighting in the evening could only be run until 22.30 h — which was much earlier than at first. The woman complained about this to the manufacturer, but he replied that the one to blame was not him, but the woman herself. She was used to keeping the lights low and dim in order to be as frugal as possible when using electricity — a habit going back to World War II. But this saving behavior appeared to ruin the battery. To function properly, the battery needs to discharge by giving a steady and strong current of electricity. The woman had unintentionally destroyed the battery. Old habits are very persistent and sometimes do not fit to new technologies.

In the eighties, electricity-saving light bulbs (eslb’s) were introduced in the Netherlands. At first, consumers did not appreciate them. The bulbs were...
quite heavy, too big to fit into some appliances, and very expensive in comparison to conventional light bulbs. In the mid-eighties, specific actions were set up by the electricity companies to speed up the introduction of the electricity-saving bulbs. The electricity companies gave their customers the opportunity to buy eslb's with a 20% discount, which resulted in rising sales. But it was only when smaller bulbs that fit most appliances became available that sales went up really high. At that time, a new problem occurred, however. The electricity-saving effects that were expected did not occur. It appeared that most people not only replaced existing bulbs with the new light-saving ones, but also used the new bulbs to illuminate places where there was no light before, such as the garden or the garage. Users appeared to be very creative in appropriating the new technology. They “invented” new applications that had not been foreseen or intended by the designers. New technologies appear to be able to evoke new and unexpected forms of behavior.

This book is about the intriguing interactions between technology and behavior. By integrating knowledge from several disciplines — such as psychology, sociology, philosophy of technology, economics, science and technology studies, and innovation and business sciences — we aim to investigate the complex interactions between technology and behavior, and thereby make the results of this investigation fruitful for technology design and policy making. How can we describe and understand these interactions? What kind of scientific disciplines can add to our understanding of them? What kind of empirical research has been done on this subject? How can we deal with these interactions in the design of products, and how can we benefit from knowledge about these interactions for policy design?

At the basis of this book lie a number of seminars with a group of scientists from all the disciplines mentioned above. The book explores the boundaries and the possible linkages between these disciplines with regard to their knowledge about technology and behavior interactions. The nature of these interactions demands a multidisciplinary point of view. The questions and problems we will meet transgress the traditional disciplinary boundaries, fully in line with the statement of Gibbons et al., (1994) about “mode 2 science.” On the one hand, the exploration in this book is expected to result in new and interdisciplinary ways of conceptualizing the relationships between technology and behavior. On the other hand, our expectation is that it will result in applications of the insights thereby gained on the practice of designers and policy makers.
2. THE NEED FOR AN INTEGRATED APPROACH

In policy domains such as environmental policy or traffic safety, technology and behavior are usually treated as separate entities. In environmental policy, attention is focused either on the development and promotion of clean technologies — i.e. technologies that cause as little environmental damage as possible — or on stimulating environmentally-friendly behavior, with the help of information campaigns directed at changing attitudes and behavior of the public. In traffic safety policy, a lot of attention has been given to economic stimuli (fines) and attitude changes (public information campaigns) in order to bring about a change in the behavior of car drivers and to decrease the number of casualties. At the same time, the automobile industry has put a lot of effort into making cars more robust and, therefore, safer. Most cars nowadays possess airbags, anti-lock brake systems, and special safety features in the doors.

This two-track approach, in our view, has reached its limits. First of all, if arrangements to stimulate the development of new technologies fail to take the behavior of users into account, unexpected and unintended side effects can occur. The changes in behavior under the influence of the new technology might cause the intended effects of the new technology to “leak away” — as was the case with the energy-saving light bulbs mentioned earlier. The abundant availability of safety devices in cars and the strong reduction of engine noise, for instance, create a very safe and comfortable environment that invites the driver to drive too fast, eliminating the effect of its technological safety measures.

On the other hand, the ‘communication and information approach’ has limitations as well. Changing people’s attitudes without taking the behavior-steering aspects of technology into account does not automatically lead to behavior change. This approach runs the risk of creating its own bias, and of being a form of ‘preaching to the converted,’ since people who are not acting in an environmentally friendly way or driving safely are often less susceptible to these forms of persuasive communication. In such cases, technological devices can be more effective instruments for changing human behavior. Speed bumps are more successful in making people drive less fast than information campaigns about the risks of driving too fast.

The need for a new and integrated approach of technology and behavior can be illustrated by taking a look at some examples in the field of Dutch environmental policy. An interesting example of this policy in the past decades is the introduction of the so-called ‘groenbak’ (‘green bin’). The
‘groenbak’ is a separate bin, placed outside the house, in which only organic waste (food and garden related) is collected with the help of a small bin inside the house. The introduction of the ‘groenbak’ was accompanied by an information campaign in which Dutch households were urged to separate organic from non-organic waste. But one of the main problems of the little bin in the house appeared to be the high speed of the decaying process during the summer months, causing a very bad smell and making the emptying of the little bin in the ‘groenbak’ quite a distasteful job. This discouraged people from separating their waste. This problem was taken away, however, when a new product entered the practice of waste separation; a small biodegradable paper bag which can be placed inside the little bin and which makes it much easier to empty and clean it. In some cases, material artifacts are able to effect changes in behavior for which information campaigns are not strong enough.

A second example concerns the emission of carbon dioxide. Dutch environmental policy has been quite successful during the last decades. Many problems, like water pollution, air pollution and acid rain, have been dealt with quite well. However, according to the ‘Milieubalans RIVM’ (2001), some persistent environmental problems remain, and are deteriorating rather than improving. One of these problems is the continually rising level of emissions of carbon dioxide (CO$_2$). Despite numerous efforts, it appears to be very hard to bend down the rising curve of CO$_2$. The most important explanation of this phenomenon is steadily rising energy consumption, which eliminates all efficiency gains of energy-using devices. As was the case with the energy-saving light bulb, the development of many new energy-saving appliances has led to an increase rather than a decrease in energy consumption. This phenomenon is often called the ‘rebound effect’. In some cases, the introduction of new technologies to solve specific problems appears to be counterproductive and to result in precisely the opposite of what was intended.

The washing machine is a good example in this context. It has become increasingly efficient in a technological sense, but has been evoking less efficient behavior. Washing machines use less energy than some time ago, but at the same time people have started to use their machines more often for small quantities of laundry (Slob et al., 1996). Figure 1-1, derived from an analysis of the use of energy-saving technologies in households in the period 1980 until 1990, shows the trend in washing practices in households in The Netherlands. The figure shows that washing machine technology has been further enhanced in that period, resulting in an electricity saving effect of about 10%. Water consumption, which has a direct relationship to electricity consumption for heating, has declined very quickly in that period. In 1990,
the average washing machine used 60 liters of water per wash against 120 liters in 1980. Electricity consumption was reduced also by changing washing habits. In the period 1980-1990, people increasingly washed at lower temperatures and made less use of pre-wash programs. This has resulted in a reduction of electricity use of about 15%. At the same time, however, the figure shows a sharp increase in washing frequency. In 1990, people used their washing machines about 20-25% more often than in 1980. Because of this unexpected change in behavior, the net effect of the technological innovations is about 10%, where it could have been more than 20%.

![Figure 1-1. Trends in washing practices (Slob et al., 1996)](image)

This type of rebound effect is not the only one, however. The unexpected effects of introducing a new technology do not always lead to a sharp increase in its use, but it can also consist in bypassing the technology or not using it at all, or in using the technology in a different way than its designers and policy makers intended. The second type of rebound effect (bypassing) is often seen in the use of control systems like movement detectors for lighting, heating, etc. Consumers devise ways to escape the control of the system, since they prefer to be in control themselves (see Van Kesteren, chapter 18). The third type of rebound effect (unintended use) is closely related to this. Jelsma (chapter 22) shows how users of dishwashers rinse their dishes under running hot water before loading them into the machine,
whereas the machine starts its cycle by rinsing as well. Another example in this context is formed by newly built energy-efficient houses equipped with new insulation materials, triple glazing, sophisticated ventilation systems, monitoring and control systems, low temperature heating systems, et cetera. In many cases, the inhabitants of these houses still open their windows for fresh air.

It can be concluded that a strictly functional approach to technology pays far too little attention to the human beings who work with devices on a daily basis and live among them day and night. In order to deal in an adequate way with societal problems regarding traffic safety and environmental pollution, an integrated approach to technology and behavior is required. Technology and behavior are always intertwined. Technologies influence human behavior, and, conversely, existing patterns in human behavior influence the use and even the resulting functionality of technologies. To be sure, the influence of technology on human behavior is not always as compelling as the example of the speed bump might suggest. The influence of many products and environments is ‘softer’ than this. Intelligent products and environments, for instance, facilitate specific forms of behavior and take over some of the actions of users, like movement indicators that switch the lights on when somebody is in the room and switch them off again when the room is empty. Moreover, such products can also influence behavior by giving feedback and providing information, leaving to the user the choice of how to deal with this information. For instance, some technologies give advice about what to do, like washing machines that indicate how full it must be loaded or how much washing powder should be used in relation to the washing load. In all these cases, technologies do not influence human behavior in a determinist way, since their effect on human behavior also depends on the ways in which the technology is appropriated.

3. **THEORETICAL PERSPECTIVES**

In the Netherlands, the interest of policymakers in the interactions between technology and user behavior was aroused by the plea of philosopher Hans Achterhuis for a ‘moralization of technology’ (Achterhuis 1995). Achterhuis observed that public concern about environmental problems was usually translated into a ‘moralization’ of people. Public debates usually focus upon morally desirable behavior: people should not shower too long, buy ecological products, use public transport instead of the car, etcetera. According to Achterhuis, this permanent moralization of people cannot be the ultimate solution, however. If it is applied in all
domains of our daily lives, it leads to a permanent reflection on our behavior, which would have a paralyzing effect and not succeed in stimulating people to change their behavior.

According to Achterhuis, therefore, we should not moralize people, but **technology**. For this, he elaborated the idea of the French philosopher and anthropologist Bruno Latour that artifacts can help to shape human behavior. According to Latour, artifacts contain ‘scripts’ — prescriptions about how to act, just like the script of a theater play or a movie tells actors what to do and how to do it (Latour 1992). A speed bump in a road, for instance, contains a clear script: slow down when you approach me, or damage your shock absorbers. This script can be seen as a form of moralization, because it embodies and reinforces the moral decision that it is not good to drive fast at places where the bump is constructed. Morality is about the question how to act, and Latour shows that not only people are able to answer this question, but artifacts as well (cf. Verbeek, 2005).

Achterhuis proposed taking Latour’s analysis as a starting point when designing technology. From an ecological perspective, this implies that technologies should not only be designed to produce as little pollution as possible, but also to steer the behavior of their users in a desired direction. Rather than demanding from consumers a continual reflection on one’s behavior, some moral decisions could be delegated to the technologies they use. The decision how much water to use when showering can be delegated to a water-saving showerhead; the decision how fast to drive on the highway can be delegated to a speed limiter. According to Achterhuis, attempts to influence human behavior in a desirable direction need to be integrated with attempts to design sustainable or safe technologies. This integration can be accomplished when the behavior-steering role of technological artifacts is taken seriously.

Achterhuis and Latour were not the first, however, to seek attention regarding the close relationship between technology and behavior. They formulated a new philosophical perspective regarding a domain that had been investigated before in other disciplines. After World War II, the steep progress of complex technology in, for instance, military applications, aviation and nuclear power, instigated the importance of correct user behavior regarding, among other things, safety, control and comfort. Insights from cognitive, experimental, and (later) environmental psychology were used to certify a proper physiological and mental interaction between users and technology. Theories, concepts and methods from these fields, such as mental models, affordances and system approaches, have been adapted to the
Chapter 1

investigation of interaction and the formulation of design guidelines. A number of partially overlapping subfields emerged, such as ergonomics, human engineering, applied cognitive psychology and human factors.

From the 1960s onwards, the scope of research on human-technology interaction has gradually extended beyond these complex systems to include parts of the larger environment, such as buildings or even cities and virtual reality, as well as smaller technological aspects of everyday life, like consumer products and computer interfaces. Subjects include safety, usability and acceptance on the side of the user in conjunction with various technological features. Additional subfields carry names such as design psychology or user/human centered design.

For an adequate understanding of the complex relationships between technology and behavior, it is not sufficient to simply explore the mutual influences between technologies and human actions. The context of use in which technologies are introduced, like existing consumer practices, habitual and conscious patterns of use, and decisions whether to buy a product or not, plays a crucial role as well. This context is important for the ways that users ‘interpret’ and ‘appropriate’ products, which in turn has implications for the possible influences of these products on human behavior. A hammer, for example, affords both driving a nail into the wall and assaulting other people; its context of use plays a decisive role in the eventual technology-behavior interaction that will occur.

Despite the available expertise mentioned above, however, many design decisions are taken without considering or making use of it. This is partly due to the rapid pace in which technology evolves and the time and money requirements that have to be met, thereby restricting the opportunities to perform proper research. But, above all, it is due to the dispersion of available knowledge over so many subfields, the lack of sharing it, and a shortage of translating results into data that can be used by designers and policy makers. This brings us back to the purpose of this book.

The theoretical aim of this book is to draw together theoretical and applied insights from scientific disciplines that investigate the various aspects of the interaction between technology and behavior. Disciplines such as psychology, ergonomics, science and technology studies, household and consumer science, safety studies, marketing research, and the philosophy of technology, all bring to light specific aspects of the ways in which technology and behavior are interwoven. In this book, we intend to show that much can be gained by bringing these fields of research into contact
with each other, and by trying to relate the various theoretical frameworks and concepts to each other.

Besides this analytical ambition, the book also has a synthetic ambition. Our aim is not only to inventory and link existing conceptual frameworks, but also to lay bare how anticipations of technology-behavior interactions can inform the design of new technologies, as well as policy-making processes. In order to do so, methodologies and conceptualizations of the design process and of policy-making processes will be investigated from the perspective of the question as to what role technology-behavior interactions play, or could play in it.

4. RESEARCH QUESTIONS AND OUTLINE OF THE BOOK

This book consists of four separate sections. Each section contains short chapters where researchers from diverse disciplines present relevant conceptual frameworks, empirical research, design approaches and policy implications regarding technology-behavior interactions. Each section ends with a concluding chapter by one of the sub-editors of this book. In order to find a starting point for analyzing the relationships between technology and user behavior, in the first section an inventory is made of the conceptual frameworks that have been developed in several disciplines that study these relationships. The disciplines involved are environmental psychology, cognitive ergonomics, safety studies, domestic and consumer sciences, science and technology studies, and the philosophy of technology. The section results in a ‘conceptual map’ in which all relevant concepts are positioned as landmarks and related to each other. By using the metaphor of a map, it becomes possible to identify districts of related concepts, the edges of their applicability, and nodes and paths as relationships and possible connections between concepts.

The second section addresses the question as to what kind of empirical research has been done in several disciplines to contribute to our understanding of the interactions between technology and user behavior. This part of the book will inventory approaches to human-technology interactions in applied scientific research. It categorizes these approaches on the basis of the role users and technologies can each play in their mutual interaction.

The last two sections of the book apply the insights gathered in the first two sections. Section three discusses the relevance of an integrated
perspective on technology and behavior for the design of technologies. The main question here is how the insights in technology-behavior interactions can be applied to the development and design of products. In the development of new technologies, interactions between technology and behavior are created implicitly, and this could happen more explicitly. The section theorizes about ways to anticipate technology-behavior relationships during the process of designing technologies, and considers methodologies for putting this anticipation into practice, including examples of design projects where the anticipation of technology-behavior relationships has played a central role.

After clarifying the dynamics of technology-behavior interactions and the possibilities of explicitly designing such interactions, policy issues come to the fore. These provide the focus of the last section of the book, guided by questions about how we can apply the insights in technology-behavior interactions to policy design and development, and what this implies for the organization of the policy-making process. This section pays attention to the points of application for policy-making that result from the analyses in the other sections of the book, and to the implications for the layout of the policy-making process itself. Separate attention is paid to issues of legitimization, since the acceptance of deliberately steering human behavior with the help of technologies cannot be taken as self-evident.

REFERENCES

Chapter 2

ACTION FACILITATION AND DESIRED BEHAVIOR

Albert G. Arnold and Petra Mettau

1. INTRODUCTION

The objective of this chapter is to provide a theoretical model and concepts that give insights in the relation between technology and desired user behavior. This knowledge is relevant for the design of adequate technological artifacts. An artifact is said to be adequate when its characteristics facilitate the user’s actions in work situations.

The insights are of a cognitive psychological nature and lie at the level of the individual user. The model and concepts presented in this chapter are based on so-called human action theory (Hacker, 1986 and Rasmussen, 1986). Human action theory offers a framework for describing a number of relevant perceptual, cognitive and motor mechanisms that play a role during human work activities. Human action theory positions the interaction between artifact and user in the context of work situations. This means that the user (or worker) interacts with the artifact in order to achieve certain goals.

Desired user behavior may be defined as human activities resulting in a desired output for the environment and the user. For the environment, this means that the user’s organization and the society at large positively value the results of the interaction.

At the level of the user, the assumption is that desired user behavior occurs when the user experiences the benefits of interacting with the artifact.
In other words, when there is a good fit between characteristics of the artifact, the user and the user’s task. The artifact should possess characteristics that invite the user to (re-)use the artifact in such a way that optimization of his or her work behavior occurs over time. The inviting characteristics of an artifact are related to the ‘affordance of an artifact’ (Norman, 1988), and the optimization of the work behavior to the concept of ‘action facilitation’ (Roe, 1984; 1988). Both concepts are elaborated in the contribution on the basis of the model of the interaction between artifacts and humans. Furthermore, relevant issues of action theory are presented, i.e. the way people prepare, execute and regulate their actions. Finally, the importance of active optimization is stressed.

2. MODEL OF TECHNOLOGY-HUMAN INTERACTION

The model must be seen as a heuristic model. It can be characterized as an ‘input-throughput-output’ model. At the input side of the model, three factors are presented, viz. the task characteristics (e.g. complexity, degree of structure, and degree of openness), the characteristics of the artifact, and the user characteristics (e.g. age, gender and intellectual capabilities). The characteristics of the artifact need special attention, as they may have a substantial impact on the ultimate behavior of the user. For example:

- The look and feel, stability and reliability, and the performance of an artifact determine to a certain extent the frequency and intensity of use.
- The degree of conformance to general operation conventions (e.g. conventions for pushbuttons, switches and turn knobs) greatly determines the degree of intuitiveness of an artifact interface, and thereby the speed of the user’s learning process.
- The navigation and support functions of the artifact can stimulate the user to optimize his or her working strategies.

It should be noted that there is a reciprocal relationship between the characteristics of an artifact and the user’s task.

The input factors determine the kind of user interaction that will occur. On the one hand, the interaction will result in a certain level of performance (in terms of effectiveness, efficiency and quality). On the other hand, the interaction will also result in individual outcomes such as satisfaction, motivation and fatigue.
The user evaluates the interaction and its results. This evaluation will have an effect on the later interactions and on the input factors. When the evaluation is positive, then a positive attitude towards the use of the artifact may occur and the artifact will be seen as adequate.

The artifact-user interaction takes place in an environment with specific characteristics, such as degree of social support, organizational culture and physical aspects.

**3. THE CONCEPTS OF ‘ACTION FACILITATION’ AND ‘AFFORDANCE OF AN ARTIFACT’**

As said before, central to the design of adequate artifacts are the concepts of ‘action facilitation’ and ‘affordance of an artifact’. A user action is facilitated by an artifact when proper cognitive, perceptive and motor processes are initiated and accommodated during the interaction with the artifact (Arnold, 1998). Proper, in turn, refers to the outcome of an action in terms of user’s effectiveness and efficiency.

The characteristics or possibilities of an artifact may directly or indirectly become clear to the user. The possibilities may be indirectly clarified by