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Interaction between occupants and sustainable building techniques

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INTERACTION BETWEEN OCCUPANTS AND SUSTAINABLE BUILDING TECHNIQUES

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Abstract

Sustainable building techniques focus on the minimisation of the environmental impacts of material use, energy consumption and water consumption. However, when occupants behave towards certain techniques in a way that differs from the intentions of the designer, the minimisation of environmental impacts might be counteracted.

In this paper a theoretical framework for the interaction between human systems and artefact systems is presented. First, characteristics of the artefact system are described that might influence the interaction with the human system. The artefact system consists of the dwelling, the sustainable building techniques that are present in the dwelling and the environment. Second, characteristics of the human system are described that are relevant to the interaction with artefacts. The human system consists of a household and the individual members of a household. Finally, the interaction between both systems is elaborated.

This framework forms the basis for a research project about the behaviour of occupants towards heat recovery balanced ventilation systems. The aim of this research project is to gain insight into the actual behaviour of occupants, the factors that influence behaviour and the influence of behaviour on the environmental performance of balanced ventilation systems.

1 Introduction

Sustainable building techniques were designed to lower the environmental impact of buildings. These techniques focus on the minimisation of the environmental impacts of material use, energy consumption and water consumption during the whole service life of buildings. The service life of a building consists of the construction, the use and the demolition. In these phases the building can affect depletion of raw materials, global warming, ozone depletion and other environmental effects (Klunder, 2005). Klunder (2005) states that many uncertainties exist with regard to the quantification of environmental impacts of dwellings. Although the collection of empirical data can increase our understanding of cause and effect, there will always be wide ‘bandwidths’. One uncertainty is the influence of occupant behaviour on the effectiveness of sustainable building techniques. When occupants behave towards certain techniques in a way that differs from the intentions of the designer, the minimisation of environmental impacts might be counteracted.

How occupants behave towards sustainable building techniques plays a central role in the PhD research project ‘Occupant behaviour and sustainable housing’. The first aim of this research project is to gain insight into actual occupant behaviour with regard to sustainable building techniques and into the effects of occupant behaviour on the environmental performance of these techniques. The second aim is to gain insight into the extent to which building professionals take into account consumer behaviour in their decisions regarding the design and the implementation of sustainable building techniques. The aim of this paper is to provide a theoretical framework for the investigation of occupant behaviour.

A distinction can be made between use and behaviour. Use is restricted to the direct interaction between an occupant and a technique to achieve a specific goal. Use actions can be defined as the
physical activities of users activating product functionalities (Kanis, 1998). Behaviour is a much broader concept than use. It encompasses all activities people perform. Occupant behaviour may influence the use of provisions that are present in dwellings. For example, drying clothes inside a dwelling may influence the use of ventilation provisions. The behaviour in dwellings and the use of provisions is different in every household, due to specific characteristics of households and characteristics of individuals within households.

Dwellings and sustainable building techniques are technological artefacts. Technology can be defined as the entire system of people and organizations, knowledge, processes and devices that go into creating and operating technological artefacts, as well as the artefacts themselves. Technology is a product and process involving both science and engineering (Karwowski, 2005).

This paper focuses on the interaction between occupants and technological artefacts. Ergonomics provides an interesting framework to study this interaction. Ergonomics is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance (IEA, 2000). Both goals of ergonomics are relevant in this paper: the optimization of human well-being and the environmental performance of the system, which consists of the dwelling and the sustainable building techniques.

A systems approach is used to study consumer behaviour towards sustainable building techniques. In this perspective, a human system and an artefact system are discerned (Karwowski, 2005). A human system can be defined as the human with all the characteristics that are relevant to an interaction with an artefact system. These characteristics can be physical, perceptual, cognitive or emotional. The human system consists of households and individuals within households. An artefact system can be defined as a set of all artefacts, as well as natural elements of the environment and their interactions occurring in time and space by nature. Artefacts are defined as objects made by human work (Karwowski, 2005). The artefact system consists of the dwelling, the sustainable building techniques that are present in the dwelling and environmental factors. The interaction between the human system and the artefact system, influences the use of the artefact system, the functioning of the artefact system and eventually the environmental performance of the artefact system. These relations are described in figure 1.

In the next section the artefact system is described, which consists of the dwelling, the sustainable building techniques and the environment. The third section pays attention to the human system, in terms of the household and the individual. The fourth section elaborates on the interaction between the human system and the artefact system. Finally, in the fifth section a research agenda is presented.
2 Characteristics of the artefact system

The artefact system consists of the dwelling, the sustainable building techniques that are present in the dwelling and the environment of the dwelling. These three parts of the artefact system interact with each other and with the human system, which will be discussed in the next section.

2.1 Dwelling

A dwelling is a building that provides different functionalities to households and individuals. First, a dwelling provides shelter. Second, a dwelling has a utilitarian function, which consists of the usability to perform activities. Third, a dwelling provides a domain to its inhabitants. Fourth, dwellings have a communication function; they provide conditions to inhabitants for making social contacts. Finally, a dwelling provides a symbolic function to its inhabitants, for example status (Priemus, 1984). Different types of dwellings exist. A distinction can be made between single-family dwellings and apartments. Dwellings can also differ in tenure. A distinction can be made between owner-occupiers and renters. Tenure form might influence the way inhabitants behave with regard to the dwelling (Elsinga, 1995).

Two types of quality can be discerned: the technical quality of dwellings and the functional quality of dwellings. The technical quality of dwellings concerns amongst others the construction, the materials use, the insulation level and the energy efficiency. The functional quality of dwellings concerns the usability of dwellings. Important concepts in this perspective are the size, the location, the accessibility and the interior of rooms.
The technical systems that are present in a dwelling also influence the usability of a dwelling. Inhabitants use technical systems in order to reach a level of living. The technological provisions in dwellings can be perceived as sub-systems within the artefact system. These subsystems are interrelated to each other and each of these systems may have a different influence on occupant behaviour.

An architect has certain visions of use in mind and certain representations of users when constructing dwellings and its technical systems. These visions and assumptions to some extent materialize in the physical shape of the dwelling as a script, i.e. as a kind of prescription of how the dwelling should be used. Dwellings consist mostly of a living room, a kitchen, a bathroom and one or more bedrooms. Architects cannot fully anticipate how inhabitants will use these different rooms. The process of inhabitants actively integrating the dwelling in their daily activities is called appropriation or domestication (Rohracher, 2003).

Households and individuals can perform different activities in the rooms that are available. Examples of activities inhabitants perform in dwellings are eating, cooking, sleeping, bathing, washing, heating and working. A distinction can be made between household activities, working activities and leisure activities. A dwelling should provide enough space for the activities individuals and households would like to carry out. Van der Werf (1989) states that besides space also the conditions under which households can perform activities are also important. Examples of these conditions are efficiency, safety and privacy.

2.2 Sustainable building techniques

Sustainable building techniques are designed to lower the environmental impact of buildings. Examples of sustainable building techniques are water-saving techniques, like an economy showerhead and energy saving techniques, like a heat pump, a balanced ventilation system and solar panels. Occupant behaviour may influence the effectiveness of sustainable building techniques. This does not apply for all techniques, but there are indications that consumer behaviour often plays a considerable role (Leidelmiejer and Van Grieken, 2005; Jeeninga et al, 2001; Macintosh and Steemers, 2005). Behaviour only plays a role when sustainable building techniques have a user component.

When occupants use certain techniques in a way that differs from the intentions of the designer, the minimisation of environmental impacts might be counteracted. A post-occupancy evaluation (PoE) of heat recovery balanced ventilation systems showed that the real CO₂-production at global level, as defined in the Kyoto agreement, was higher than the calculated optimum and also higher than the base case with only natural ventilation (Macintosh and Steemers, 2005). Jeeninga et al. (2001) found that the actual energy use of households living in dwellings with the same physical and thermal characteristics can vary up to a factor two.

Many examples of human artefact interaction in this paper relate to heat recovery balanced ventilation systems. A heat recovery balanced ventilation system is a specific balanced ventilation system that provides a controlled way of ventilating a dwelling while minimizing energy losses. Balanced ventilation systems supply and exhaust approximately equal quantities of fresh outside air and polluted inside air, respectively. A balanced ventilation system has two fans and two duct systems. The heat recovery balanced ventilation system reduces the costs of heating ventilated air in the winter by transferring heat from the warm inside air being exhausted to the cold supply air (Dubo-Centrum, 2006). Occupants can influence the functioning of a balanced ventilation system by maintenance and use. First, occupants can clean the filters that are present in the ventilation unit, the ducts, the inlet grilles and outlet grilles. Second, occupants can adjust the ventilation capacity by operating a switch, which has three positions. Third, occupants can open windows to provide additional ventilation. Sustainable building techniques can be integrated in the dwelling itself or in the direct environment. The focus in this project is on sustainable building techniques that are present in dwellings. However, the environment in which the dwelling with its sustainable building techniques is located does influence the use of the dwelling and its provisions. These relations are elaborated in the next section.
2.3 Environment

Factors from the environment may influence occupant behaviour towards the dwelling and sustainable building techniques that are present in the dwelling. First, factors from the direct environment of the dwelling may play a role. Weather conditions may influence behaviour towards sustainable building techniques. When the sun heats a dwelling with large south-facing windows, occupants might use sunblinds to prevent overheating. Another example of the influence of weather conditions on behaviour is ventilation behaviour. Wind velocity, precipitation and sunshine influence the opening of windows (Dubrul, 1988). Furthermore, noise that is produced in the direct environment may influence the use of a dwelling. This noise can be produced by traffic, neighbours or an industry. Noise may lead to the closing of windows (Wouters and De Baets, 1986).

Second, non-human resources on a macro and micro level may influence behaviour of households and individuals. In the use phase of sustainable built dwellings, energy consumption and water consumption are important. An increase in price of these commodities may lead to more energy-conscious or water-conscious behaviour. Whether price affects behaviour depends highly on individual and household characteristics and on the percentage of their income that they can spend on the energy or water bill.

Third, the influence of important referents may influence the behaviour of individuals and households. These important referents can be neighbours, family-members or friends.

3 Characteristics of the human system

The human system can consist of one individual, in case of one-family households, but it can also consist of more individuals that live together in a household. Individuals within a household interact with each other and with the artefact system. In this section, first characteristics and dynamics of households are described. Second, individual characteristics that might influence human-artefact interaction are worked out.

3.1 Household

A household is a social unit, which performs activities aimed at the satisfaction of everyday material needs and which creates material conditions for their immaterial needs (Zuidberg, 1981). The purpose is to achieve well-being for the members of the household group. In most situations the group provides its own human resources. Human resources are means vested in individuals that can be used for attaining goals and creating events. Examples are cognitive insights, psychomotoric skills, affective attributes, health, energy and time. Human resources, together with non-human resources as money, appliances and other goods form the household resources. The dwelling with its sustainable building techniques forms a central non-human resource.

With information, facilities and services from outside organizations, households generate an output. This output is the level of living a household achieves, which can be defined as the quantity and quality of goods consumed or available. The level of living is the result of all household activities. Households strive to bring their level of living in line with their ultimate goals for life, the standard of living. This is a set of standards and values concerning daily life and representing the views and ideas of the members of the household about the way to live (Zuidberg, 1981). The standard of living is not a rigid entity. It is partly formed by the values and norms in society and it adapts itself continuously to external and internal circumstances.

Households aim to achieve a balance between the standard of living and the level of living. This balance works as a controlling factor. If the level of living does not meet the standard of living, the household will adjust the household activities in order to reach the standard of living. This evaluation of the level of living by the members of a household in relation to their standard of living is called well-being (Zuidberg, 1981).
Households perform activities within their dwelling to achieve their level of well-being. These activities include household activities, like washing, cooking and cleaning, working activities and leisure activities, like inviting friends and watching television. The activities people perform in their dwelling may have an influence on the use of sustainable building techniques and on the environmental performance of these techniques. When every individual within a household showers for fifteen minutes everyday, the savings of an economy showerhead might be counteracted. How households carry out activities depends on the habits of the household and individual preferences of household members. However, general household characteristics may also influence the way activities are performed and the frequency of activities. In this perspective, the size of a household, the composition of a household, the life stage of a household and the education level may be important.

3.2 Individual

The way individual household members interact with the dwelling and the sustainable building techniques also depends on individual characteristics. This section discusses characteristics and processes that are important in this interaction process. Individuals perceive the world through their senses, mainly by sight, hearing, odour, taste and their awareness of their body in space. The environment people live in can be considered as a supplier of stimuli that reach people through sensory channels, which in turn trigger stimulus and response mechanisms. First there is input through sensations, followed by perception, cognition, action and outcome. Input is the stimuli from the environment that can be quantified, measured and reproduced. Perception is how much the individual actually takes in after the signal has passed through the person’s psycho-sensorial filters and the meaning the person attributes to it. Cognition is the process related to elaboration and decision-making. Action is the result of the decision and outcome is the result of the action (Bonapace, 2002). This process from stimulus to behaviour is displayed in figure 2.

![Figure 2. From stimulus to behaviour. Source: Bonapace (2002)](image)

3.2.1 Perception

Perception is the process by which people select, organize and interpret sensory stimuli into a meaningful and coherent picture (Assael, 1995). Stimuli are more likely to be perceived when they conform to individuals’ past experiences, conform to occupants’ beliefs, when they are not too complex and relate to a set of current needs. Once exposed to a stimulus, occupants’ perceptions go through three distinct phases: attention, comprehension and retention. Attention is the process of noticing a stimulus or certain portions of it. This is a selective process: individuals are likely to notice stimuli that relate to their needs and conform to their experiences. Comprehension is understanding and interpreting the message. Individuals are likely to interpret a stimulus to agree with their beliefs. A stimulus can be noticed, interpreted and quickly forgotten. Individuals tend to retain in their memory those stimuli that are relevant to their needs (Assael, 1995).

The artefact system in this study, a dwelling with sustainable building techniques, is multi-model, which means that it addresses different senses simultaneously. The way individuals perceive these stimuli influences their behaviour towards the artefact system. Perceived comfort is an important factor that may exert influence on behaviour. Slater (1985) defines comfort as a pleasant state of
physiological, psychological and physical between a human being and its environment. If an individual is not able to perceive a stimulus, the experience of comfort will not change. For the comfort experience of a dwelling, it is important that there is a congruent relationship between the various senses. If an individual, for example, smells fresh air coming from an inlet from a balanced ventilation system, but sees a dirty inlet grill, the sensory impressions do not match. This in turn may lead to a negative experience of comfort.

3.2.2 Cognition

When an individual has perceived stimuli from the environment, cognitive processes may lead to action. This action can include an activity or specific use of an artefact. Several psychological characteristics may play a role in these cognitive processes. Two basic concepts that are often named as underlying motivation for behaviour are needs and values (Van Raaij, 1998).

Individual needs are strongly related to the motivation of people to behave in a certain way. A need is what an individual experiences when there is enough discrepancy between the perceived present situation and the perceived ideal situation. This ideal situation can be defined as a goal. Needs and goals are both necessary conditions for the motivation of an individual to perform behaviour (Van Raaij, 1998).

A fundamental way to investigate the motivation of individuals to perform behaviour is the investigation of values. A value is a more or less permanent belief that individuals have towards preferable modes of conduct and end states (Van Raaij, 1998). Gutman (1982) proposes in his means-end theory that the usefulness of products is often not related to the attributes of products, but to the consequences of products. The concept of consequence is defined as every direct or indirect result of a person’s behaviour. Consequences can be desirable or undesirable. Desirable consequences are also known as benefits (Coolen and Hoekstra, 2001). Both functional and psychosocial consequences are important for individuals to realize their values. Functional consequences are direct consequences of the use of a product. When a person uses an economy showerhead, for example, less water will be used than with a regular showerhead. A psychosocial consequence of the same behaviour may be that the person feels more environmentally friendly. The importance of consequences is based on their ability to satisfy personally motivating values and goals of people. The central idea in means-end chain theory is that occupants choose the actions which produce the desired consequences and which minimize the undesirable consequences. If a balanced ventilation system produces noise, for example, it depends on the values and goals of an individual how he will act towards the system. If the individual values silence, he will probably switch it off. However, when the individual values fresh air higher than silence, he will probably accept the noise and will keep the system running.

The second linkage in means-end theory is the one between consequences and attributes of products (Coolen and Hoekstra, 2001). To be able to make a choice between different goods, the consumer must learn which goods possess the attributes that produce desirable consequences. Although this research project does not focus on the choice between products, the linkage between attributes and consequences is still important. Concrete and abstract attributes determine the usability of products and consequently the consequences of usage. If a person cannot reach a switch to operate a balanced ventilation system or if a person does not know how the system works, for example, the switch can be left in the same position all the time. A consequence may be that the ventilation in the dwelling is insufficient over a long period of time.

3.2.3 Action

Cognitive processes may eventually lead to action. Action is defined as activities in dwellings and use of specific artefacts. When an individual has decided to act towards an artefact, knowledge about the operation and functioning of artefact systems can influence this action. If people have a lack of knowledge about the operation and functioning of artefact systems, their behaviour might exert a negative influence on the functioning of the system and the effects of the system. Frick et al. (2004)
distinguish three forms of knowledge that might be of influence on environmental behaviour: system knowledge, action-related knowledge and knowledge about the effectiveness of sustainable behaviour. These concepts can also be applied to behaviour towards sustainable building techniques in dwellings. System knowledge is then defined as knowledge about the technical specifications of the artefact system. Action-related knowledge is defined as knowledge on the intended operation of the artefact system and effectiveness knowledge as knowledge about the effects of the functioning of the system. Frick et al. (2004) state that action-related knowledge and effectiveness knowledge have a direct effect on behaviour. In contrast, system knowledge is more remote from behaviour, exerting influence on behaviour by affecting the two other knowledge types. Therefore, strengthening action-related knowledge and effectiveness knowledge might enhance a good interaction between a human system and an artefact system. Macintosh and Steemers (2005) found in their research on the use of balanced ventilation systems that information to residents might play a significant role in the effectiveness of this artefact system. Through information about the operation of the system the CO₂-production could be reduced by 9% over the existing situation.

Besides knowledge, experience with specific artefacts may influence the use of those artefacts. Individuals get used to behavioural patterns in processes, which is also known as habit behaviour. When individuals are confronted with a new artefact, they might copy their behavioural patterns to the new artefact. If the design of the artefact is similar to the design of the known artefact, it takes little adaptation of skills to perform behaviour (Freudenthal, 1999). However, when the design of the new artefact is different and different behaviour is needed, the new artefact is action incompatible (Groot-Marcus, et al., 2005). This may lead to unexpected use and consequently unexpected effects of artefacts.

3.2.4 Outcome

The performance of behaviour leads to a certain outcome. The extent to which this outcome complies with the expectations of the individual will lead to satisfaction or dissatisfaction (Van Raaij, 1998). If people are satisfied with the outcome, the probability that they will repeat their behaviour increases. If they are dissatisfied with the outcome, they might change their behaviour toward the artefact or dismiss the artefact.

In this perspective a distinction can be made between satisfying attributes of artefacts and dissatisfying attributes of artefacts. Swan and Combs (1976) postulated that consumers judge products on a limited set of attributes, some of which are relatively important in determining satisfaction, while others are not critical to consumer satisfaction but are related to dissatisfaction when performance on them is unsatisfactory. Attributes can be defined as dissatisfiers when the performance or absence of the desired feature leads to dissatisfaction (Johnston, 1995). An example of a dissatisfier is the amount of water that an economy showerhead provides. Attributes can be defined as satisfiers when performance or absence of the feature does not necessarily cause negative feelings (Johnston, 1995). An example of a satisfier is the possibility to buy an economy showerhead in ten different colours.

Outcome can be related to direct effects of artefact use or indirect effects of artefact use. Direct effects are for example noise and comfort. These effects can be perceived by an individual and might lead to a different use of the artefact immediately, for example turning down the thermostat or closing a window. An example of an indirect effect of behaviour is the yearly energy bill. For individuals it is hard to relate the yearly energy bill to the behaviour they performed and this decreases the probability they will change their behaviour. However, research shows that immediate or timely feedback of energy consumption will cause residents to change energy wasting behaviour to energy conservation behaviour (McCalley and Midden, 2002). These results show that direct outcome of behaviour has a larger influence on behaviour than indirect outcome. Outcome that is even more remote from the individual is the influence of behaviour on the environment.

Another distinction can be made between satisfaction with outcome on a short-term and on a long-term level. In general, people strive to satisfy short-term needs first before long-term needs. This may lead to behaviour that has a negative influence on the well-being of people on the longer term.
4 Insights into human artefact interaction

This section pays attention to the interaction between human systems and artefact systems. As stated above, the artefact system consists of dwellings, sustainable building techniques and the environment. The human system consists of households and individuals. First, attention will be paid to the interaction of the household system with the artefact system. Second, the interaction between individuals and artefact systems is elaborated.

4.1 Interaction between households and artefacts

The household mechanisms described in section 3.1 are concentrated on a social group and do not include the physical interaction with the environment. Only input from non-human resources from the environment are included. However, a household also generates an output of non-human resources, like waste and energy emissions. The Consumer-Technology Interaction model (Groot-Marcus, 2005) provides a framework for the interaction between a household and its environment. This model is based on a technological approach where households are systems in which material and immaterial elements function for the satisfaction of everyday needs in interaction with society and the environment. The emphasis in the model is on the interaction between human and material factors. This interaction takes place when material resources are used in household activities. The model is displayed in figure 3.

![Figure 3. Consumer-Technology Interaction model. Source: Groot-Marcus et al. (2005)](image)

Household activities form a central element in the system. In these household activities the interaction between technology and behaviour takes place. Household activities also form the link between household resources, the level of living and the level of well-being. When a new technology is introduced in a household system, the balance between resources, level of living and standard of living may be disturbed, followed by a change in household activities (Groot-Marcus et al., 2005). Sustainable building techniques can be perceived as innovative technology, since most individuals in households do not have any experience with these techniques. The domestic activities in which sustainable building techniques are integrated produce outcome in terms of services and side effects, and consequently a level of living. If this level of living does not comply with the standard of living, the well being of the household is at stake.
The functional performance level of a household activity is an important indicator for the level of living. When a technology is functionally incompatible, the performance level of an activity is altered and may become incompatible with the living standard. Households can apply two different strategies to regain the balance in the domestic system: restoring the level of living and adaptation of the standard of living. Households can restore their level of living by using another combination of resources in their activities (Groot-Marcus et al., 2005). For example, households may turn off a balanced ventilation system and open the windows instead. Households can also adopt the new situation as the new standard of living (Groot-Marcus et al., 2005). Environmentally conscious people for example, might accept a possible decrease in comfort when using an economy showerhead, because they have changed their standard of living.

Besides functional compatibility, also the extent to which household members are able to perceive the effects of household activities influences the extent to which the household system reacts to new technologies. If individuals within the household do not notice effects of household activities, no response is needed to maintain the usual household routine and the level of living (Groot-Marcus et al., 2005).

4.2 Interaction between individuals and artefacts

The individual interacts with the system in terms perception, cognition, action and evaluation of the outcome (see section 3.2). For these interactions, the design, the functionalities and the (side) effects of the artefact are relevant. This section discusses the interaction process between individuals and artefacts. This interaction process is displayed in figure 4.

![Individual-product interaction](image-url)

The description of the interaction process starts with the perception by the individual of the artefact system. An individual can perceive the design of the system and the functioning of the system, in terms of performance and (side) effects. First, the individual can perceive the design of the artefact. The actual use that will result from this perception depends on the individual’s conceptual model of the artefact and the goals of the individual. Does the individual know how the system works and how it should be operated? What does the individual want to achieve by using the artefact? In this stage of the interaction process, visibility of the design is important. The visibility of controls of an artefact system acts as a good reminder of what can be done with the system (Norman, 1988). Second, the individual can perceive stimuli from the functioning of the artefact system, in terms of performance...
and (side) effects. Feedback is an important design principle in this perspective. Feedback is sending back to the individual information about what action has been done and what the results of the actions are (Norman, 1988). When the interface of an artefact system provides an output display, the individual is informed about the results of an action. However, a dwelling and sustainable building techniques often do not provide an output display. Therefore, an individual is dependent on his perception of the physical state of the system. The extent to which an individual can perceive the system state is important for the interpretation of the system state and the evaluation of the system state.

The second stage in the interaction process is the cognition phase. In this phase the individual decides which use actions he will perform. The evaluation of the physical state of the artefact system forms the input of the cognition phase. In ergonomics literature, a discussion exists about the extent to which cognition plays a role in the interaction process. When behaviour towards artefacts is goal-directed cognition plays a larger role than when behaviour is habitual. Norman (1986) posits in his theory of action that the interaction between systems and individuals is always goal-directed. In this theory, every interaction starts with the goals of the individual that lead to an intention for action and subsequently to a use action. However, Kanis (2002) states that experience with a system can lead to habitual behaviour. He uses a framework of skill-based behaviour, rule-based behaviour and knowledge-based behaviour to explain this (Rasmussen, 1986). In this framework skill-based behaviour represents sensory-motor performance during acts or activities, which take place without conscious control. The flexibility of skilled performance is due to the ability to compose, from a large repertoire of automated sub-routines, the sets suited for specific purposes. At the next level of rule-based behaviour sequences of subroutines in familiar situations are typically controlled by stored rules or procedures, which are selected from previously successful experiences. Behaviour that is performed on the basis of skills and rules can be perceived as habitual behaviour. In unfamiliar situations, faced with a situation for which no skills or rules are available, the control of the behaviour must move to a higher conceptual level, in which behaviour is goal-directed and knowledge-based. (Rooden, 2001). Kanis (2002) proposes that the role of cognition decreases when an occupant has gained experience with the usage of a product. This achieved familiarity tends to automate behaviour, which means proceeding as much as possible on skill-based behaviour. Whether behaviour is goal-directed or habitual, the cognition phase will eventually lead to a use action.

The third stage in the interaction process is the use action itself. A use action can be defined as the external physical activities of individuals activating product functionalities (Kanis, 1998). A functional prerequisite for the design is that individuals should be able to use the artefact system with appropriate mental and physical effort. Which physical action is required depends on the interface of the artefact system. A good relationship between the placement of a control and its function makes it easy to find the appropriate control for a task. This design principle is defined as mapping (Norman, 1988). In product operation use actions often involve manipulation, i.e. touching or holding a product or a product part, and moving it by exerting force (Kanis, 1998). The way individuals perform these actions depends on their physical and psychological characteristics. The physical characteristics set limiting boundaries for the direct use of products. If a person does not have the strength to open a window, the window will stay closed. The usability of artefacts and the compatibility between the characteristics of the artefact and the characteristics of the individual are important in this perspective. Knowledge and experience may also set limiting boundaries for use.

In the fourth stage of the process the use action changes the physical state of the artefact system. When in use, a functional requirement for a system is that is should produce minimal side effects, such as noise and environmental impact. Furthermore, the technical characteristics of a product should be effective, which means they should provide preconditions to fulfil minimal performance requirements. This means for example that the capacity of a ventilator of a balanced ventilation system should be sufficient to ventilate all rooms in a dwelling.
The change in the physical state of the system will start a new interaction process between the individual and the artefact system. The individual will perceive the performance and the effects of the system and this will lead to a future use action. The extent to which the interaction process described in this paper is applicable to occupant behaviour towards dwellings and sustainable building techniques will be investigated in this research project. In this project attention will also be paid to the question if behaviour is goal-directed or habitual.

5 Research agenda

In this paper a theoretical framework was constituted for the investigation of occupant behaviour toward sustainable building techniques. This framework will be used to gain insight into the actual behaviour towards specific sustainable building techniques and into the factors that influence this behaviour. The data on actual behaviour will be used to estimate the environmental impact of sustainable building techniques.

The empirical research focuses on heat recovery balanced ventilation systems. The effectiveness of a balanced ventilation system is dependent on occupant behaviour. Occupants can for example exert a negative influence on the environmental performance of the system by opening windows or by turning the system off. The focus of the research will be on how occupants use the system, why they use it in that way and on the effectiveness of the system in terms of environmental performance. The investigation of the factors that influence behaviour forms an important part of the research. Building professionals can use this information to adjust or improve the design of the system. Important questions in this perspective are worked out here. Is ventilation behaviour goal-directed or habitual? Are individual household members able to perceive the effects of the system and how does this influence their behaviour? Do general household characteristics influence the behaviour towards the system? Is there a relation between the activities of households and ventilation behaviour? Do dwelling characteristics, like type and size, have an influence on ventilation behaviour? Do characteristics of the ventilation system, like the placement of the switch or the type of windows, influence ventilation behaviour?

Different research methods will be applied in this research project. First, twenty interviews will be carried out with occupants of single-family dwellings and apartments to gain insight into actual behaviour and the factors that influence behaviour. These interviews will be combined with an inspection of the dwelling and the ventilation system and an observation of how occupants use the ventilation provisions that are present in the dwelling.

Second, a quantitative survey is carried out to give insight into the behaviour of a larger group of occupants. The data that result from this survey will be used to estimate the environmental performance of the system.

Third, measurements will be performed in dwellings to gain insight into the actual use of the ventilation system. These measurements are performed to validate the results of the quantitative survey and to gain insight into the environmental performance of the system. The measurements will be combined with diaries of occupants.
References

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