Energy Research & Social Science 14 (2016) 46–60

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Original research article

How do occupants decide their interactions with the building? From qualitative data to a psychological framework of human-building-interaction

Jörn von Grabe

University of Liechtenstein, Institute of Architecture and Planning, Fürst-Franz-Josef-Strasse, 9490 Vaduz, Liechtenstein

ARTICLE INFO

Article history:
Received 1 September 2014
Received in revised form 4 January 2016
Accepted 6 January 2016

Keywords:
Human behavior
Buildings
Context
Decision theory
Energy consumption
Building simulation

ABSTRACT

Because human interaction with buildings significantly influences the energy consumption of buildings, predicting this type of behavior has become increasingly important in recent years. Improvement of understanding provides a basis for improving the quality of behavior-predicting models and requires an adequate consideration of the context of human-building interactions. The relevant context must be thoroughly identified and organized, and the knowledge gleaned from this analysis can then be used to theoretically conceptualize the problem. It is a plausible assumption that models and theories from disciplines traditionally dealing with human behavior, namely psychology and sociology, are best suited to conceptualize energy-relevant human interactions with buildings. A method for the identification and organization of relevant context attributes and their interrelations was proposed in Ref. [1]. Based on the results presented there, this paper exemplifies the transition from this qualitative knowledge of context to the conceptualization of a problem-specific psychological theory that promotes a better understanding and predictability of energy-relevant interaction with buildings. The aspect chosen to illustrate this process, which is considerably developed in this paper, refers to the decision processes of the building occupant that occur prior to executing the interaction.

1. Introduction

Building occupants interact with the equipment elements of a building in order to optimize their local environment. For example, individuals may open windows to improve air quality or room temperature, they may close the sun screen to reduce internal radiation, or they may switch on a ventilator to increase air movement. All of these interactions influence the building's energy consumption to a certain degree. Consequently, if a building's energy consumption is to be optimized during the planning phase, these interactive behaviors must be considered. Particularly in building simulations, which are often used to numerically predict the thermal behavior and energy consumption of newly planned buildings, it is essential to predict human interaction numerically to achieve realistic results.

In a previous paper, I argued that an adequate consideration of context is imperative for a realistic prediction of energy-relevant human interaction with buildings [1]. For the purposes of this discussion, the terms "context" and "adequate" require some explanation. Traditionally, the term "context" refers to something that "surrounds" the individual but does not include attributes of the individual her/himself. However, in this paper, for reasons of compactness, the term "context" also includes individual attributes that refer to internal states and processes, such as need, experience, and knowledge. Formally, context refers to the multitude of context attributes; for example, individual knowledge, air temperature, or room orientation, as well as their complex interrelations.

The term "adequate" relates to two aspects: [2] first, it relates to a representation of the relevant context that is both as comprehensive as possible and meaningful in terms of the specific problem. A systematic method to achieve this goal was suggested and explained in [1]. Second, "adequate" relates to the methods that are used to understand and conceptualize interactive behavior based on knowledge of the relevant context. Likely, theories and models from disciplines that traditionally deal with the analysis of human behavior, namely, psychology and sociology, will be best suited to this task, though a number of adaptations based on the specific properties of this field will certainly be necessary. The above mentioned systematic method for the identification of context, which results in a meaningful but merely qualitative description of the relevant context, informs us about the nature of

E-mail address: v.grabe@buildingsimulation.eu

http://dx.doi.org/10.1016/j.erss.2016.01.002
2214-6296/

the potentially useful theories from these disciplines for a theoretical conceptualization.

The present paper deals with the second of the two described aspects of the term "adequate", i.e., the identification of theories from psychology that are potentially useful for the understanding and the conceptualization of energy-relevant human interaction with buildings. The paper pursues two goals simultaneously. First, it attempts to demonstrate the transition process that starts from the pre-theoretical, qualitative description of context – a result of the systematic method presented in Ref. [1] and briefly summarized in Section 2 – via the identification of generic psychological theories that are generally suitable and applicable to the problem in principle (explained in Section 3) to the layout of a theoretical framework that specifically addresses the problem by refining and extending these generic theories (explained and discussed in Sections 4 and 5). Second, because it is beyond the scope of a journal article to cover every psychological framework and its specific extensions that might be derived from the qualitative analysis of context, this process is exemplified by an aspect of interaction that can be considered to be central to any numerical prediction model of energy-relevant human interaction with buildings. This aspect relates to the question of how occupants decide which equipment element(s) they want to operate to satisfy their diverse needs. It is therefore the second goal of this article to outline in detail a psychological framework that conceptualizes the underlying cognitive processes of such specific decisions. This framework is presented and discussed in Sections 4 and 5.

2. Systematic identification of the context of energy-relevant interaction

This section will summarize the essential aspects of the method for the systematic identification of context, presented in detail in Ref. [1]. Specifically, the second subsection presents an example of a typical result that can be obtained from the method, which forms the basis for the remaining sections of this paper.

2.1. The systematic identification and organization of the context of energy-relevant human interaction with buildings

The fundamental concept of the method involves acknowledgement that energy-relevant interaction with buildings does not occur in laboratories or other research settings, but exists in everyday people's lives in their "natural habitats." This motivates us to focus on the "naive layman." We are interested not only in terms of seeing the occupant as a research subject, but in studying the individual in order to determine a methodological approach to the problem. If we want to know how and why an occupant interacts with a building, it makes sense to take the perspective of this occupant, to comprehend how he or she perceives the world and likely organizes and makes use of the information at his or her disposal. Therefore, it is valuable to take a close look at these everyday lives.

A number of established methods to observe everyday life exist, such as Barker's and Wright's fieldwork between the 1940s and the 1970s [3,4] or the ethnographic approach [5,6]; however, these methods do not provide the desirable insights into the inner thought processes that take place during interactions with buildings. Alternatively, interview techniques are often used to obtain information about individual worldviews, attitudes and beliefs (e.g., [7–11]), yet this data is usually acquired in situations in which the participant is disconnected from everyday life, so the results often lack the required ecological embeddedness. To address these limitations, an alternative data acquisition method has been proposed in Ref. [1]. which is based on an established method called "protocol analysis" [12,13], but adapted to the field-specific requirements of energy-relevant human interaction with buildings. In protocol analysis, subjects are asked to verbally express their thoughts during the implementation of a task. These verbalizations are recorded and analyzed to gain insights into the elements and structure of the task-accompanying cognitive processes. At least two different versions of protocol analysis can be distinguished, namely concurrent reports, which are given during task implementation, and retrospective reports, which are given after task completion. When appropriately cued, retrospective reports are more informative and reliable than concurrent reports because they do not interfere with the process of task implementation (see Refs. [14–19] for a discussion).

The version of retrospective reports developed and proposed in Ref. [1] for the analysis of energy-relevant human interaction with buildings is characterized by a number of features. Reports are scheduled on a regular basis (daily, weekly or monthly), and should include distinctively different conditions (e.g., different seasons). To provide appropriate cues, protocolling is suggested to be conducted in the setting in which the relevant interaction took place. Subjects are asked to actively visualize the situation they want to report and to use the first person, present tense and everyday language while reporting.

A corresponding small-scale pilot study has been designed and conducted to generate applicable data as well as knowledge about the type of data that can be obtained by such a method, which is needed to prepare larger-scale studies. The main steps to reduce effort for this pilot study comprised reduction of the sample size to a single person and implementation as self-report. Both steps limit generality of the data, and it is discussed in Ref. [1] why this reduced design nevertheless yields valuable data.

Specifically, the type of analysis of the observational raw data is an important methodological decision that aims at limiting subjectivity of the results. This analysis contains two steps: first, the identification of general attributes of context; and second, the meaningful organization of these attributes. These statements require some explanations. The aim of the method is the identification of the *general context* of energy-relevant interaction. However, the protocol data reflects rather *concrete* situation-specific experiences of contextual factors; thus it is necessary, in a first step, to raise the information given in the protocol to the more abstract level of *categorical attributes of context*. For example, the concrete experiences appearing in the protocol data, which are highlighted here in bold, can be assigned to the categorical attribute rainfall: "*. . . and that, during my absence, it will not be* ***raining*** *through the window into my room . . .*" and "*. . . at least the top window is reasonably protected against* ***rain*** *. . .*" (Table 2 in Ref. [1]). Thus, attributes of context are not real-world entities, but rather fundamental categorical units to which concrete, real-world entities can be assigned. This step makes analysis less specific to the protocol data, and thus generalizes it. For the proposed method, attributes of context are the fundamental unit of analysis.

In a second step, these attributes were organized by the interrelations between attributes that could be identified from the analysis of the protocol data. Two fundamental types of organization were identified: *hierarchical* relationships, or "type-subtype" and "part-whole" relations; and *ontological* relationships, which refer to a non-hierarchical, complex network of relationships between attributes. Both formats generally agree with findings from cognitive psychology in terms of knowledge representation in the human memory, whereby models of knowledge representation usually assume a semantic organization of knowledge as a network of interconnected nodes that partially includes category-instance relations (e.g., [20–26]).

The first step of the hierarchic organization of attributes was the assignment of attributes to categorical domains of reality. Altogether, four domains were identified: *environmental condition*;