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Short communication

Decision models and data in human-building interactions

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ABSTRACT

Occupant interaction with buildings is responsible for much of the variations in energy consumption observed in real buildings. The understanding of these behaviors and their underlying psychological processes is therefore essential for the development of energy saving strategies for buildings. In turn, such understanding requires an adequate theoretical conceptualization. A recently proposed psychological framework conceptualizes one of the central cognitive processes during interaction: the decision on how to interact with the available elements of the building in order to satisfy individual needs. Currently, this model lacks concrete empirical confirmation. To prepare the ground for a large scale validation study, this article analyzes data which were originally acquired for another (thus far unpublished) study. Though these data are not tailored to the specific needs of the framework validation, the obtained results tend to confirm the underlying assumptions of the model.

1. Introduction

If the building design allows the occupant to interact with the equipment elements of the building in order to regulate the internal environment according to his or her needs; for example, by operating windows, sun screens, conditioning systems, etc., then such interactions will influence the building's energy consumption to a large extent [1–6]. This human influence needs to be considered for the planning of buildings, and a central issue for understanding and considering such human interactive behavior is a thorough conceptualization of the involved psychological processes.

The present article is based on and tightly linked to a previous publication proposing a framework for a psychological human decision model [7]. This model comprises six sub-models, each of which describes a specific sub-process of the entire process. The development of these sub-models has been discussed extensively against the background of the research results of other fields, yet the sub-models thus far lack specific empirical confirmation. Therefore, the presented analysis attempts to substantiate a number of assumptions made for the sub-models through the statistical examination of subjective, questionnaire-based ratings addressing several environmental conditions. Since the data was not specifically acquired for this purpose (but for another, thus far unpublished study), the entire set of sub-models could not be tested, and the design of the study is not tailored to the specific needs of the decision model. Therefore, this analysis primarily serves the aim of a preliminary testing; it is a pilot-study that prepares the ground for a larger-scale study. Against this background, the statistical analysis was kept as simple as possible.

The available, questionnaire-based data comprises subjective ratings concerning sensation, acceptability, wish to change conditions and the respective intention to operate an element of the building, and the analysis examines the significance of the statistical relationship between these ratings. Note that the nature of the data indicated a priority to focus on parts of the data related to sensations above neutral. Note further that the available data set encompasses ratings on room climate, solar radiation intensity and glare, yet this article primarily focusses on solar radiation intensity and mentions the other data only when contextually necessary.

2. Decision model

To better understand the steps taken in the analysis, it is necessary to have a basic understanding of the decision model. The model is subdivided into six sub-models:

- State prior to decision
- Valence of the change of local environmental conditions
- Force to execute operation
- Costs of operation
- Secondary costs and benefits of action
- Action tendency.

The *state prior to decision* describes the relevant context in which the decision takes place. Relevant information includes, for

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example, the characteristics of the space, the states of the available equipment elements, as well as the internal and external environmental conditions. Most importantly, the model assumes that the search for potential routes of interaction is elicited by the dissatisfaction of a specific need; for example, the need for comfortable thermal conditions. This dissatisfaction is expressed on an acceptability scale ranging from 0, representing acceptable conditions, to 3, denoting highly unacceptable conditions.

There are two major assumptions in the sub-model that defines the *valence of the change of local environmental conditions*: First, individuals know which environmental conditions are *generally* causally linked to the currently dissatisfied need. This assumption is formally described by the instrumentality that a change of a specific type of environmental condition would have for the change of dissatisfaction. Second, they know which of these conditions is *currently* contributing, and to what extent, to the dissatisfaction concretely experienced in the current situation, which is formally described as the individual's expectancy that the change of a *specific* condition will contribute to the reestablishment of satisfaction. If, for example, the thermal comfort need is dissatisfied, the actor will likely not consider changing the current lighting or noise conditions, because these are only weakly, if at all, linked to the satisfaction of thermal comfort; formally, these conditions have a low instrumentality. Rather, the options considered will involve changing potentially relevant thermal conditions, such as air temperature or solar radiation intensity (high instrumentality). Which of these potentially relevant conditions is most appropriate to be changed depends on the concrete environmental conditions (as described in the first sub-model). If, for example, solar radiation is very intense, reducing solar radiation can be expected to contribute essentially to the reestablishment of thermal satisfaction (high expectancy). If solar radiation is low, yet temperatures are high, a considerable contribution cannot be expected from the change of solar radiation (though the instrumentality is high, the expectancy is low in this concrete situation). In this situation, lowering the temperature can alternatively be expected to promote satisfaction. Instrumentality and expectancy combine to yield the environmental potential, which describes the potential of the current environmental conditions to improve satisfaction in the specific situation. The environmental condition with the highest potential to improve satisfaction is the condition for which change is assigned the highest valence.

The third sub-model determines the *force to execute the operation* of the available equipment elements. The model describes which operation—from the subjective perspective of the actor, is the most promising means of exploiting the considered environmental potentials. This is termed "operational potential". Usually, different operations can be assigned an operational potential to exploit one and the same environmental potential, and the model assumes that actors usually know which operations make sense to be considered in the current situation and which do not. For example, tilting a window and opening a window widely are both actions that can be expected to lower internal air temperature, and might therefore be considered in a decision process that aims at lowering the temperature; however, switching on the light does not have such potential, and as a consequence is not considered. This operational potential can again be formally expressed as an expectancy (to exploit the environmental potential). This expectancy depends on attributes of the equipment element, such as the size of the opening in the case of windows, as well as features of the context, such as current wind speeds, temperature differences between inside and outside, etc. Based on his or her knowledge, which has been gained from previous operations in comparable situations, the actor assigns respective expectancies to the available operations for each considered environmental potential (for example, reducing solar radiation by operating the sun screen). The operation with the highest multiplicative combination of environmental potential and expectancy to exploit this potential is assigned the highest force to be executed.

The *costs of operation* sub-model describes the costs attached to considered operations, which include the degree of operability of the element or the admissibility of the operation. The latter refers to the rules and norms of the supra-individual system in which the actor is integrated. For example, the most preferred operation might be to remove essential parts of the clothing; however, in certain supra-individual systems, this action may collide with the dress-code. The higher the costs attached to an operation, the more this operation is restricted.

Further costs, as well as benefits of a potential action are described by the *secondary costs and benefits of action* sub-model. These secondary effects are not immediately attached to the operation, but rather signify in the consequences of the operation and their interference with needs other than that which elicited the decision process. For example, opening a window might be expected to improve satisfaction of the need for thermal comfort, but may also be expected to reduce satisfaction with the need to implement the task, as more noise might be transferred into the room, thus interfering with the ability to focus on work. However, this type of secondary effect can also be beneficial, indicating that the action is expected to improve the situation beyond the satisfaction of the need in question. For example, opening a window might additionally be expected to improve air quality, thus satisfying the need for olfactory comfort. Secondary effects of action are clearly context-dependent; for example, whether the noise level increases depends, among other things, on the respective external environmental conditions of the specific situation.

In a final step, the *action tendency* is determined by balancing the force of the considered operations, the costs and the secondary effects.

3. Data acquisition

The original study examined different levels of solar radiation intensity and their influence on verbally expressed sensation, acceptability, wish to change conditions and the preferred operation to achieve this change. For this purpose, four separated cabins were created, each of which was exposed to solar radiation in a different manner. Cabin 1 was isolated from direct solar radiation, while cabins 2 through 4 were each located at a façade that was glazed with floor-to-ceiling glazing, which was oriented to the southwest. To introduce a larger variance of incident solar radiation beyond the natural variation, each cabin was equipped with an internal screen with different solar transmission values. These screens also acted as diffusors, which thereby allowed the solar radiation intensity on the body surface to be mostly independent of the angle of incidence. The resulting ratio of solar transmittance was around 1:2:4 (cabins 2–4). The participants' orientation was parallel to the façade so that one side of the body was exposed to the radiation. The experiments were conducted in Aldrans, region Innsbruck, Austria.

Participants were requested to remain in a cabin for 30 min and to busy themselves with reading or a comparable activity (material was provided). At the end of each period, they were asked to fill out a questionnaire. Each participant started the experiment in cabin 1, the "acclimatization cabin", in order to acclimatize to the base level environmental conditions of the test and establish a comparable metabolic rate. They then changed to one of the window cabins. After a 30-min period in the window cabin, participants always first returned to the acclimatization cabin for the next 30 min to re-acclimatize to the base level, and then went on to the next window cabin, and so on. Consequently, one experimental run returned