If when is better than if (and while might help): on the importance of influencing mental models in EUD (a pilot study)

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Abstract

In this paper, we present a preliminary study aimed at improving the users' mental model of an automatic smart home system based on trigger-action rules. We hypothesized that a computational model of how the rules are evaluated and activated, coupled with a linguistic form of the rules that clarifies the difference between events and states, may improve accuracy in identifying buggy rules, which may eventually increase end-users' acceptance of this type of systems. This pilot study was conducted with non-programmers and provided some evidence in support of this hypothesis.

Keywords 1

End-User Development (EUD), trigger-action rules, mental models

1. Introduction

End-User Development (EUD) is defined as the possibility for people without programming experience to create or modify their applications [12]. EUD approaches focus on empowering users beyond their involvement in the design phases, as advocated by user-centered design, and propose a vision in which design, learning, and development are an inherent part of technology in use [6, 16]. Empowering users is particularly important today, as the Internet of Things (IoT) is pushing for digitalizing everyday objects: in this respect, EUD may prove crucial to facilitate the adoption of this technology [1, 17].

Programming is difficult for non-experts because it often requires expressing solutions in ways that are not familiar to them [15]. The concept of rule may provide an intelligible metaphor for programming digital technologies since it embeds the idea that specific actions need to be taken in specific situations [5].

In the context of IoT-based smart devices, the programming approach based on contextual rules has evolved in the so-called *trigger-action programming* for which a rule takes the specific form of an action that is performed upon the occurrence of condition. Such a metaphor is supposed to be easily graspable by users since IoT devices are usually either sensors that detect events in the world or actuators that operate changes in the world (of both).

The simplicity of this approach is demonstrated by the success of web-based services, like IFTTT (https://ifttt.com/) [20]. Nevertheless, for an effective programming of IoT devices, it is important to allow more expressive triggering conditions and more elaborate actions [1, 3, 8, 19]. When the triggering conditions become more complicated (for example allowing multiple conditions), the rule metaphor becomes less simple and users are more prone to errors, for example by inaccurately composing events or mistaking events with states [10, 2]. Another source of confusion are users' wrong or inaccurate mental models of the actual functioning of the system: for example, because users assume default states when there is none [21].

Indeed, mental models are important cognitive constructs that can explain how people interact with the world and specifically with complex artifacts [7]. Roughly, a mental model is a simplified

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representation of the mechanism and working of an artifact that a user develops in order to make sense of the artifact itself and to effectively use it [13, 18]. Users' mental models are not necessarily correct and complete representations of an artifact, but they may have both predictive and explanatory power for understanding the interaction between the user and the artifact.

Mental models can and should be communicated to the user by proper design [14] but it might also be effective to communicate them verbally, by providing the user with an adequate description of how the system works. Regardless of their correctness, different mental models of the same object may lead to dramatically different user-object interactions: Halasz and Moran's study [9] is a compelling example of how two different, albeit both correct, descriptions of the functioning of a reverse-polish calculator can lead to different performances.

2. Research hypothesis

The present study aims at investigating how end-users conceptualize EUD in smart homes and at providing simple but effective design hints to improve understanding of trigger-action rules.

Specifically, we would like to encourage accurate mental models by providing a better representation of how rule-based systems works and by fostering a recognition of different important concepts by imposing linguistic constraints to the rules.

Regarding the first aspect, there is some of evidence that proper and short instructions may contribute to develop accurate mental models [11] and that mental models arising from an explicit description of the working mechanism (hereafter called "computational models") are more effective than models arising from a simple description of the procedure/rules of a given system (hereafter called "descriptive models") [9]. We therefore posit Hypothesis 1 as follows:

- *Hypothesis 1*: a short description of the cyclical mechanism of evaluation and activation of the rules may improve the understanding of the effects of trigger-action rules.

Regarding the second aspect, one key point is the difference between events and states [10]. In some EUD implementations there is the possibility to associate a condition involving events and/or states with the trigger [4]. Yet the distinction between events and states is difficult to understand because they are often closely related [8] (for example, the state "the door is open" is related to the event "the door opens"). Several types of error may be attributed to the confusion between these two concepts [2]. We therefore posit Hypothesis 2 as follows:

- *Hypothesis 2*: expressing the rule through a linguistic form that clarifies the event/state distinction may improve the understanding of the effects of the rule; we proposed the form WHEN <event> WHILE <state or set of states> DO <list of actions>

3. The study

The study is based on the one presented by Brackenbury and colleagues [2] with some modifications. It consists of eight scenarios in a smart-home setting, each one accompanied by two rules that may or may not realize the purposes stated in the scenario. In some cases the rules are correct (i.e., they realize the described scenario) while in other cases they are buggy (i.e., conditions described in the scenario do not activate the rules or their activation have outcomes other than those intended – i.e., different from those described in the scenario).

Before the study, the users are offered a short tutorial with some examples about the distinction between events and states (see **Figure 1)** and they have been told that rules have the form: **WHEN** <*event*> **WHILE** <*state or set of states*> **DO** <*list of actions*>. However, they can be shortened as **IF** <*event and/or set of states*> **THEN** <*list of actions*>.

Following this, the scenarios were presented in random order. In the rules of the scenarios, the use of the *WHEN/WHILE/DO* form is alternated (in a randomized way) with the form *IF/THEN*.

Half of the subjects receive a computational description of how the system works that specifies the cyclical nature of the rule evaluation-and-activation system (i.e., a "*computational model*") while the other half receive a simpler description of the possible rule structures (i.e., a "*descriptive model*").

Therefore, the study has two *between-subject* conditions (i.e., computational vs. descriptive models; cf., Hypothesis 1) and two *within-subject* conditions (i.e., the two possible format/structure of the rules; cf., Hypothesis 2).

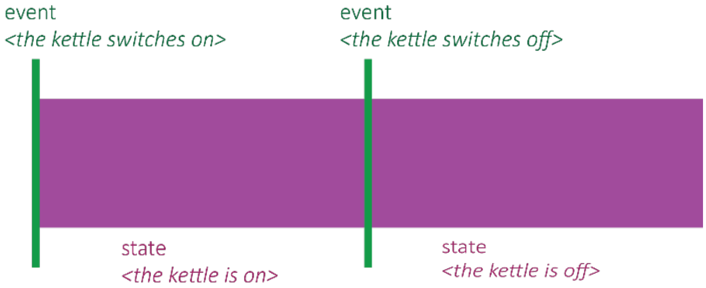

Figure 1: Picture from the tutorial illustrating the difference between events and states

3.1. Preliminary results

The study has been piloted with 12 bachelor students from the Department of Psychology and Cognitive Science of the University of Trento; none of them had knowledge of, or prior experience with, computer programming.

Although the results are preliminary, they are promising and clearly show a trend that supports both hypotheses.

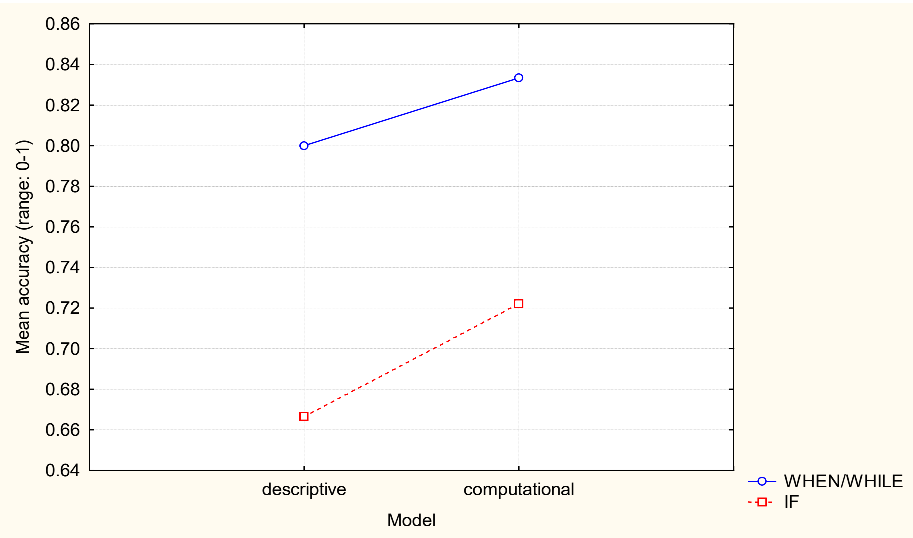

Figure 2. Mean accuracy in the recognition of rules' behavior for the two types of model (descriptive vs. computational) and the two rule formats (When/While vs. If)

As suggested by the plot in **Figure 2**, accuracy in the recognition of rules' behavior is higher when the rules are presented in the *WHEN/WHILE* format than when presented in the IF format (Hypothesis 2) and for participants who have been exposed to the computational model rather than the descriptive model (Hypothesis 1).

An analysis of variance (ANOVA) partially confirmed the trends by showing a significant main effect of the format of the rules. The main effect of the model was not significant (see **Table 1**).

Table 1. Repeated measures ANOVA with one between-subjects factor (mental model) and one within-subjectsfactor (format)

Repeated Measures Analysis of Variance Sigma-restricted parameterization Effective hypothesis decomposition					
	SS	**Degr. of - Freedom**	**MS**	**F**	**p**
Intercept	12.45522	1	12.45522	160.9903	0.000000
mental model	0.01077	1	0.01077	0.1393	0.717651
Error	0.69630	9	0.07737		
FORMAT	0.08148	1	0.08148	5.2105	0.048352*
FORMAT*mental model	0.00067	1	0.00067	0.0431	0.840228
Error	0.14074	9	0.01564		

4. Conclusion and further works

The results of this pilot study are initial evidence supporting our hypotheses: Our manipulations seem to be effective in increasing the participants' understanding of the rules' behavior and of their effects. Consistent with our hypotheses, the use of a WHEN/WHILE format for the rules and (possibly) the computational description of the system seems to improve users' mental models of how the smart-home automatic system works.

The full study is ongoing. It will include a measure of comprehension of the training and more detailed analyses of the results.

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