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Modeling of Proximity-Based Expectations

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Abstract

Expectations play a crucial role in many domains, including HMI. In this paper we examine a specific type of expectations resulting from the proximity of interface control elements. We briefly present the results of an experimental smart phone task that manipulated the relationship between control element proximity and the closeness of the corresponding goals. We present a modeling approach for proximity-based expectations and compare model predictions from an ACT-R model and experimental results.

Keywords: expectations, interface design, cognitive modeling, ACT-R, HMI

Introduction

Expectations are hugely important in everyday life. They are an important element of learning about, dealing with and ultimately mastering our environment. More specifically expectations allow us to anticipate future states of the environment. This allows both for better mental and action preparation (Umbach et. al. 2012) but also for improved action-feedback learning loops (Friston & Kiebel 2009, Gallistel, 2005).

In the case of proximity and causality a type of expectation might have evolved that lead us (largely subconsciously) to expect similar or close objects in our environment to be functionally or causally related. We will refer to them as *proximity-based expectations*. Modeling these expectations is an important puzzle piece in the quest towards making quantitative predictions about usability. By quantifying their exact impact, we can improve future models of user interaction with technical interfaces by adding expectations to them.

We created a cognitive modeling approach in ACT-R that utilizes one of the possible implementations of proximity-based expectations and compared its output with experimental data.

We also devised an experimental setup that aims to empirically capture the effect of a specific design decision - here spatial proximity of control elements - on reaction times and user errors. To this purpose we created a smart phone app that enabled the construction and configuration of geometrical shapes.

Experiment

Participants were asked to recreate three geometrical shapes of varying shape, filling color and periphery color. Each trial started with the app presenting a screen that contained the three shapes to be recreated and buttons that could be used to initiate the manipulation of each shape (see figure 1, left panel).

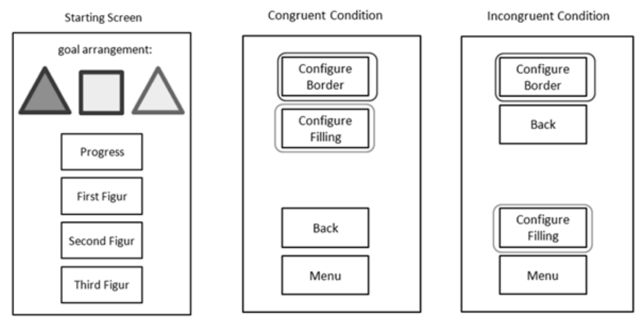

Figure 1: Starting screen (left) and exemplary menu state for the congruent condition (left) and the incongruent condition (right).

The participants first had to choose the shape (square or triangle) and then had the choice between manipulating the color of periphery or interior. The participants were given constant feedback about the state of the shape so that they could track the effects of their manipulations. The menu always contains four buttons, with two spatially close buttons on the top and the bottom of the screen respectively.

We tested two experimental conditions: in the "congruent condition" - in accordance with the proximity compatibility principle - buttons that were used for similar purposes (like the button for manipulating shape and the button for manipulating color in figure 1, middle panel) were situated close to each other. Conversely, in the "incongruent condition", buttons for similar purposes were situated away from each other (figure 1, right panel). The participants had to finish a total of ten trials, each starting with the presentation of the three shapes and ending with the correct creation and configuration of all three shapes.

ACT-R expectation model

Two model approaches for modeling proximity-based expectations were proposed by Lindner & Russwinkel (2015). In the current paper we will present one of them, the action tendency approach).

Both for the model implementation and the concept description in this paper we made use of the cognitive architecture ACT-R (Anderson et al., 2004) and its terms, respectively.

The goal of the modeling approach is to quantify both the processes involved in building up expectations and those that translate those expectations into changes in overt behavior. The main idea consists in linking co-occurring goals and actions and to create action tendencies from these links.

In the experimental task let us assume that a participant has the goal to configure the border of a shape and then successfully does so by pressing the button „configure border". The button itself but also the buttons close to the button „configure border" should from now on be associated with the goal „configure the border". They should also be associated with related goals like "configure the shape" (which is a meta-goal of „configure the border") and "configure filling" (which is a sub-goal of this meta-goal).

More technically speaking, if a goal/sub-goal G is achieved by using control element E the following processes occur: First, the elements close to E, including E itself, C(E) are associated with the goals close to G, including G itself, C(G) (e.g. sub-goals, sub-goals of the meta-goal) (see figure 2). Second, action tendencies are created that "encourage" the use of elements from C(E) when the goals from C(G) or reoccur.

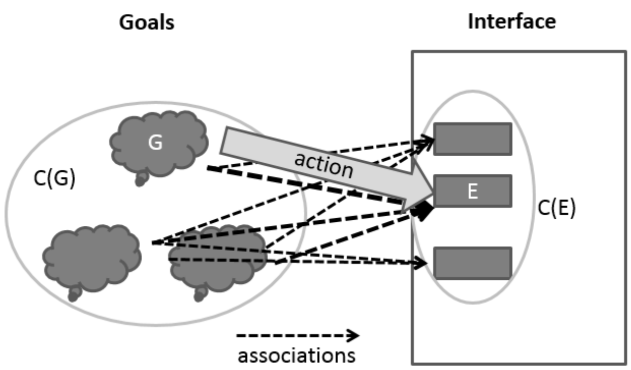

Figure 2: Associations between closely related goals and spatially close control elements

The "action tendency" implementation comprises the direct and immediate creation of all specific action tendencies related to the current goals and interface elements. In ACT-R this translates into the creation of precise productions that couple the present goal and related goals with spatially close control elements anytime a control element is successfully used. The starting utilities of the productions (and thus the probability of them being used) grow with closeness to the original goal G and spatial closeness to the original control element E.

So far, in ACT-R production utilities only change after a reward is given at the end of a successful action sequence that contained the production. In order to implement the utility needed for our expectation approach, we had to extend the utility mechanism to also include the change of utilities of production that were not previously fired.

One important implementation decision is what the action tendency actually entails. In our model we conservatively stuck the interpretation that the participant will first look to an expected position when encountering a new screen. They will also prepare to press the "expected" button before it is visually encoded.

General Model Predictions

The expectations will lead to more frequent visual encoding of the correct control element first if the interface is constructed following PCP. This should result in overall faster completion time of tasks. On the one hand, visual search is cut short if the expectation already points to the correct control element. On the other hand, the motor preparation for the expected button should also lead to a decrease in motor action, as both movement and motor preparation can be skipped.

We also expect fewer errors to be committed in an interface following PCP compared to one that does not. Our model, however will not address this hypothesis. In the discussion we will elaborate on a model extension that could reflect this phenomenon.

Experimental and modeling results

	n	Model w/o expectations	Model w/ expectations	Experiment
Congruent Condition	19	29,2	29,0	29,3
Incongruent Condition	17	29,5	29,6	36,9

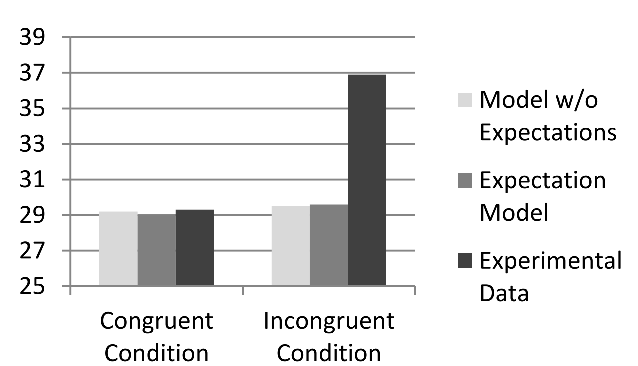

Figure 3: Total Completion Times in s (first trial excluded)

Discussion and Outlook

In order to better reflect experimental reaction times - especially in the incongruent condition - the model is currently being altered to include the tendency to click screen elements that are expected to be helpful for the task without double checking its function first. This could also help to better fit the experimental results concerning errors committed, since participants committed a substantial overall amount of errors and errors were more frequent in the incongruent condition.

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