Wienrich, Carolin; Zander, Thorsten O.; Gramann, Klaus (Hrsg.): Trends in Neuroergonomics. Tagungsband 11. Berliner Werkstatt Mensch-Maschine-Systeme; 7.–9. Oktober 2015, Berlin Berlin: Universitätsverlag der TU Berlin, 2015. - 334 S. ISBN 978-3-7983-2803-7 (online)
doi: 10.14279/depositonce-4887

Lindner, S. and Russwinkel, N. (2015). The Effect of Design Decisions on User Expectations - A modelling approach. In: Wienrich, C.; Zander, T. O.; Gramann, K. (Eds.): *Trends in Neuroergonomics. Proceedings of the 11th Berliner Werkstatt Mensch-Maschine-Systeme* (pp. 98-102), Berlin, Germany. doi: 10.14279/depositonce-4887

The Effect of Design Decisions on User Expectations - A Modeling Approach

Stefan Lindner[1], Nele Rußwinkel[1]

Keywords: Expectations, Cognitive Modeling, Usability, Proximity Congruency Principle

Abstract

In this paper we take a closer look at the influence of interface design decisions on users' expectations regarding the function of contained control elements. In a smart phone app-based experimental setup we manipulated the proximity of control elements that were used for related task goals. We report the influence of this manipulation on task completion times an overall task errors. We describe two approaches on how to model the underlying processes of expectation buildup and their effect on subsequent user actions using the cognitive architecture ACT-R.

[1] Technische Universität Berlin, Kognitive Modellierung in dynamischen Mensch-Maschine-Systemen, Correspondent email: stefan.lindner@campus.tu-berlin.de

Introduction

Modern information technology greatly expands in functionality. In order to preserve practical relevance for a diverse group of users, usability aspects have to be kept in mind when designing user interfaces.

According to Wickens & Carswell (1995) useful concepts to improve the usability of displays and control element structures are “perceptual proximity” and “process proximity”. Control Elements are in perceptual proximity if they are spatially close, have similar appearance, use the same physical dimensions or are coded similarly. Process proximity describes how close the functions of control elements are connected with each other in the work flow. The *proximity compatibility principle* suggests that process proximity and perceptual proximity of control elements should align (Carswell, 1990). This suggestion is backed up by experiments that show that tasks are sped up and produce fewer errors if the user interface abides by the principle (Goettl et al., 1991; Liu & Wickens, 1992; Mori & Hayashi, 1995).

We are interested in reasons for these findings and suggest that expectations could play a major role. Expectations play a vital role both in the structuring of our environment and in action preparation (Umbach et. al. 2012) and regulation (Friston & Kiebel 2009, Gallistel, 2005). In the case of proximity and causality expectations might have evolved that lead us (largely subconsciously) to expect similar or close objects in our environment to be functionally or causally related.

In this paper we are specifically interested in the question whether goals that are related within a task go along with expectations that the control elements needed to satisfy those goals will be spatially close. We will use a cognitive modeling approach to explore the possible involvement of these expectations in the use of a novel smart phone app.

The models will be implemented in the cognitive architecture ACT-R (Anderson et al., 2004). Cognitive architectures aim to provide extensive and well specified computational frameworks for human cognition. On the one hand, this forces a precise formulation of theories since all relevant processes have to be specified in great detail. It also enables a precise prediction of resulting human cognitive processes and behavior, which in turn can be used (by comparing model predictions to actual behavior) to gauge the validity of the theory.

Experimental Design

In order to empirically capture the effect of a specific design decision - here spatial proximity of control elements - on reaction times and user errors, we created a smart phone app that enabled the construction and configuration of geometrical shapes.

Task:

Participants were asked to recreate 3 geometrical shapes of varying shape, filling color and periphery color. Each trial started with the app presenting a starting screen that contained the 3 shapes to be recreated and buttons that could be used to initiate the manipulation of each shape (see figure 1, left panel).

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 contained 4 buttons, with 2 each spatially close to each other on to the top and the bottom of the screen respectively.

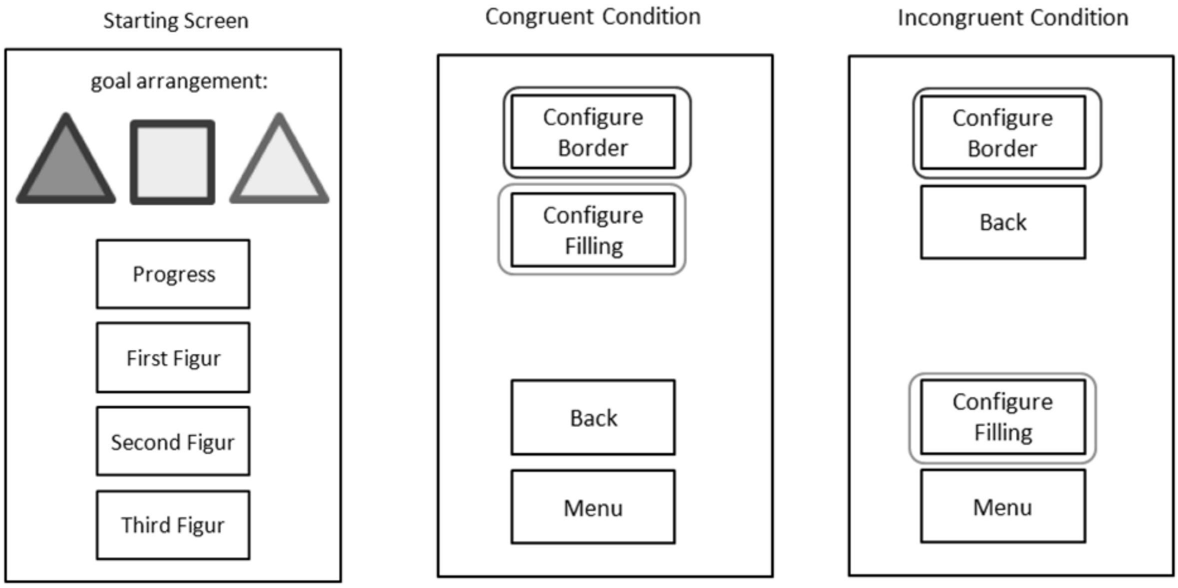

Figure 1. Starting screen (left) and exemplary menu state for the congruent condition (left) and the incongruent condition (right).

Independent variables:

In the "congruent condition" (CC) - 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" (IC), buttons for similar purposes were situated away from each other (shape 1, right panel). The participants finished a total of 10 trials, each starting with the presentation of the 3 shapes and ending with the correct creation and configuration of all 3 shapes.

Dependent variables:

The main dependent variables were the completion times of each trial and the number of errors committed during each trial. Errors consisted mainly of taking steps backwards within the menu and of reconfigurations of shapes.

We expected participants to have lower completion times in the congruent condition of the experiment and to commit fewer errors in that condition. We also expected participants to learn faster in the congruent condition.

In both conditions we expected participants to show learning progress, i.e. to be faster and make fewer mistakes with increasing trial number.

Modeling Approaches

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 task at hand 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 now in the future 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). Second, action tendencies are created that “encourage” the use of elements from C(E) when the goals from C(G) or reoccur.

We suggest two different ways to implement this idea.

The first 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.

The second implementation would take a “detour” over associations. Associations would be created that link

a. control elements and properties (here: button and position) and

b. properties and goals (here: position and goal)

When a new situation is encountered, action tendencies would then be created by linking

1. those associations that contain goals related to the goal at hand and

2. those associations that contain control elements present in the current situation.

In ACT-R this would entail the creation of association chunks that are stored in the declarative memory. More general “meta-productions” would create action tendencies out of present associations.

We expect models to make different predictions concerning the time lag between using interface elements and concerning the generalization of expectations. If action tendencies are created directly, those tendencies are accessible much faster (since they are created directly after performing an action) but are also less flexible since they only apply to the specific environment of the current task and interface.

In contrast, if it is the associations that are remembered, action tendencies will be available slower (since they are only created once a new situation is encountered). On the flip side, action tendencies are now also being created in new situations that contain goals or interface characteristics of a different task in the past. It thus enables the learning of expectations and action tendencies across different tasks by generalizing into a broader range of new situation and interface environments.

Concerning errors, the second implementation predicts a larger number of a certain type of error in our experimental setup where participants will press a key that has the same coordinates as the key pressed on the previous screen. A more complete test of differing error predictions would be provided by testing the same participants in similar environments where the second implementation would predict a smaller amount of errors compared to the first one if the setups are structured similarly and a larger amount if they are structured differently concerning the spatial setup of buttons.

Results

We tested a total of 45 (age range 20-69 (mean=30.7); 29 female) participants but had to exclude 9 participants that showed patterns of deliberate disregard of experimental instructions or that felt unable to complete the task. This left us with data of 17 participants in the incongruent condition and 19 participants in the congruent condition. 34 out of 36 (94.4%) of the participants owned a smart phone using it an average of 3.4 (std=3.1) hours per day.

Completion times differ between trials and generally decline over time. The largest gap in completion time however, is between the very first trial and the remaining trials. An ANOVA investigating the influence of trial number and congruency found a significant influence of trial number ($p<0.001$; $F=16.8$; $df=9$) but not congruency ($p=0.1$; $F=2.6$; $df=1$) on reaction times.

Errors differ between trials, the largest difference again being between the error committed in the very first trial and the remaining trials. An ANOVA investigating the influence of trial number and congruency on number of errors committed found a significant influence of trial number ($p<0.001$; $F=12.45$; $df=9$) and congruency ($p<0.05$; $F=4.39$, $df=1$) on total number of errors committed.

Discussion

As expected, the display manipulation and the concomitant differing compliance with the Proximity Compatibility Principle lead to differing number of total errors committed. The failure to find a significant influence of congruency on reaction times could be due to a too small sample size (as we did find a tendency) or due to accuracy-speed tradeoff effects.

We will now take a closer look at the precise reasons for these findings. Once the described model approaches are implemented in ACT-R, a model fit regarding both errors and completion times over the span of all trials will provide a better picture of the involved processes. Further experiments might also be necessary to test the generalization of design-based expectations across tasks.

Literature

Anderson, J. R., Bothell, D., Byrne, M. D., Douglass, S., Lebiere, C., & Qin, Y. (2004). An integrated theory of the mind. *Psychological review, 111*(4), 1036.

Carswell, C. M. (1990). Graphical information processing: The effects of proximity compatibility. In *Proceedings of the Human Factors Society 34th Annual Meeting (pp. 1494-1498).* Santa Monica, CA: Human Factors and Ergonomics Society.

Friston,K. & Kiebel, S. (2009). Predictive coding under the free-energy principle. *Philisophical Transactions of the Royal Society, Biological Sciences. 364*, 1211-1221.

Gallistel, C. R. (2005). Deconstructing the law of effect. *Games and Economic Behavior, 52(2)*, 410-423.

Goettl, B. P., Wickens, C. D., & Kramer, A. F. (1991). Integrated displays and the perception of graphical data. *Ergonomics, 34*(8), 1047-1063.

Liu, Y., & Wickens, C. D. (1992). Use of computer graphics and cluster analysis in aiding relational judgment. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 34*(2), 165-178.

Mori, H., & Hayashi, Y. (1995). Visual interference with users' tasks on multiwindow systems. *International Journal of Human‐Computer Interaction, 7*(4), 329-340.

Umbach, V. J., Schwager, S., Frensch, P. A., & Gaschler, R. (2012). Does explicit expectation really affect preparation?. *Frontiers in psychology, 3*.

Wickens, C. D., & Carswell, C. M. (1995). The proximity compatibility principle: its psychological foundation and relevance to display design. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 37*(3), 473-494.